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13. ABSTRACT *(Maximum 200 words)*
THE PROPOSED ACTION IS THE CONSTRUCTION AND OPERATION OF A PILOT SYSTEM FOR CONTAMINATED GROUND WATER CONTAINMENT AT ROCKY MOUNTAIN ARSENAL, CO. THIS SYSTEM CONSISTS OF A GROUND WATER COLLECTION SUBSYSTEM, A WATER PURIFICATION SUBSYSTEM AND A GROUND WATER RECHARGE SUBSYSTEM. THE PROPOSED PILOT OPERATIONS WILL SUPPLY DATA FOR THE DEVELOPMENT OF A FULL SCALE CONTAINMENT SYSTEM WHICH WILL BE INITIATED IN THE FALL OF 1977 AND WILL BE CONTINUED UNTIL START OF PROPOSED FULL-SCALE OPERATIONS IN THE FALL OF 1979. THIS EIS IS APPLICABLE TO THE PILOTING OF A SYSTEM TO ACCOMPLISH THE FIRST OBJECTIVE OF THE IR PROGRAM; THAT IS, CONTAINMENT AND TREATMENT OF CONTAMINANTS MIGRATING ACROSS THE BOUNDARY OF RMA. AFTER COMPLETION OF THIS PILOT WORK, THE SYSTEM WILL BE EXPANDED TO COMPLETELY MEET THE OBJECTIVE. THIS SYSTEM EXPANSION WILL BE ADDRESSED IN A SUPPLEMENT TO THIS STATEMENT.

14. SUBJECT TERMS
GROUNDWATER, TREATMENT, ECOLOGY, MONITORING WELLS, DIMP, DCPD, WASTE BASINS

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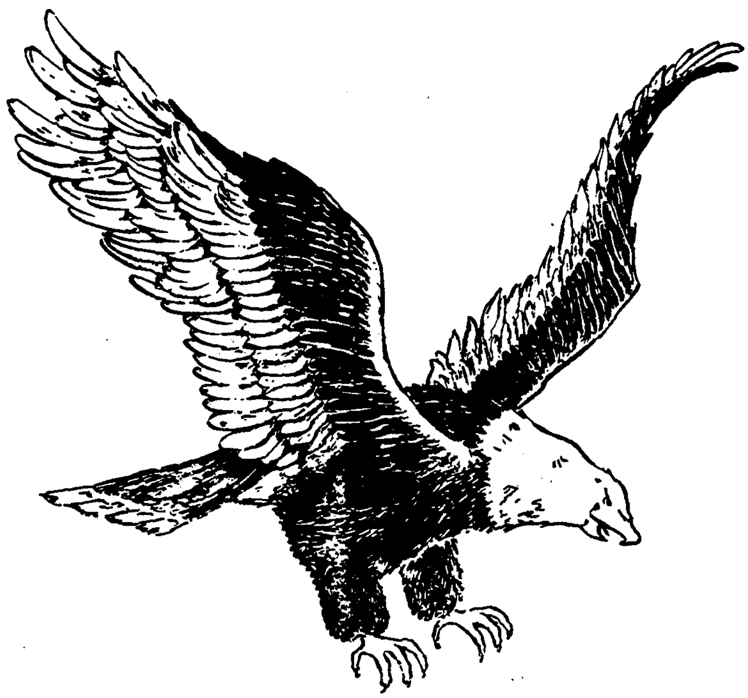
INSTALLATION RESTORATION
OF
ROCKY MOUNTAIN ARSENAL

PART I - PILOT CONTAINMENT OPERATIONS
DRAFT ENVIRONMENTAL IMPACT STATEMENT



FEBRUARY 1977

DEPARTMENT OF THE ARMY
OFFICE OF THE PROJECT MANAGER
FOR
CHEMICAL DEMILITARIZATION AND INSTALLATION RESTORATION
ABERDEEN PROVING GROUND, MARYLAND 21010

81295R07

DEPARTMENT OF THE ARMY
OFFICE OF THE PROJECT MANAGER FOR
CHEMICAL DEMILITARIZATION AND
INSTALLATION RESTORATION

INSTALLATION RESTORATION OF ROCKY MOUNTAIN ARSENAL

PART I - PILOT CONTAINMENT OPERATIONS DRAFT ENVIRONMENTAL IMPACT STATEMENT

FEBRUARY 1977

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SUMMARY SHEET

INSTALLATION RESTORATION
OF
ROCKY MOUNTAIN ARSENAL, COLORADO

PART I PILOT CONTAINMENT OPERATIONS

(x) Draft ( ) Final Environmental Statement

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1. Name of Action: (x) Administrative ( ) Legislative

2. The proposed action is the construction and operation of a pilot system for contaminated ground-water containment at Rocky Mountain Arsenal, Colorado. The proposed system consists of a ground-water collection subsystem, a water purification subsystem, and a ground-water recharge subsystem. This will be the second step taken toward compliance with Cease and Desist Orders issued by the State of Colorado against Rocky Mountain Arsenal. The first step has identified ground-water pollutants and established the feasibility of the proposed system to deal with the existing problem. The proposed pilot operations will supply data for the development of a full-scale containment system. The action is scheduled to be initiated in the fall of 1977 and will be continued until full-scale operations begin in the fall of 1979.

3. This is not a major Federal action. The pilot system is not anticipated to have significant adverse impact on the environment nor is it anticipated that it will be environmentally controversial. This action has been developed with enhancement of the environment as the primary concern.

4. Alternatives to the proposed action include no action and delayed action. Additionally, operational alternatives to the system are discussed.

5. Comments on the Draft Environmental Impact Statement will be solicited from:

a. Department of Health, Education and Welfare.

b. Environmental Protection Agency.

(1) Office of Federal Activities.

(2) Region VIII.

c. Department of the Interior.

d. State of Colorado.

(1) Division of Planning, Department of Local Affairs.

(2) Denver Regional Council of Governments.

(3) Department of Health.

e. Environmental Defense Fund.

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I. DESCRIPTION OF THE PROPOSED ACTION

A. Background

1. Location and Prior Use

Rocky Mountain Arsenal (RMA) occupies 17,000 acres in Adams County, Colorado, ten miles northeast of the city center in Denver and is immediately north of Denver's Stapleton International Airport (Figure 1). Prior to Federal acquisition of the property in 1942, land development was primarily agricultural. Originally encompassing 19,776 acres, RMA was established at an estimated cost of $62,415,000 to produce toxic chemical and incendiary munitions. The total investment in land and facilities is estimated at 115 million dollars, and the replacement value is estimated at 400 million dollars.

2. History and Current Mission

a. During World War II, RMA manufactured and assembled 87,000 tons of chemical intermediate and toxic end item products and 155,000 tons of incendiary munitions. At the end of the war, RMA production facilities were placed in a standby status. From 1945 to 1952, the primary Arsenal activities were: maintenance and renovation of Chemical Corps supplies and equipment, industrial mobilization planning, and demilitarization of obsolete munitions.

b. In 1946, certain portions of the Arsenal were leased to private industry for chemical manufacturing. The major lessee, Shell Chemical Company (SCC), has leased a considerable portion of the manufacturing facilities at RMA since 1952. Shell has made major alterations and additions to the facilities for the manufacture of various pesticides. All leased facilities are covered by a recapture clause in the event of a national emergency.

c. The second major construction phase in the Arsenal's history occurred when RMA was selected as the site for construction of a facility to produce GB nerve gas. This manufacturing and filling facility was completed in 1953. Manufacturing operations continued until 1957 and munitions filling operations continued until 1970. From 1959 through 1962, RMA produced biological anticrop agent and, from 1965 through 1969, emptied Cyanogen Chloride (CK) and Phosgene (CG) bombs.

d. The passage of PL 91-121, enacted 19 Nov 69, issued a new era in chemical warfare materiel disposal and a third phase in the Arsenal's history. Before 1969, disposal of chemical warfare materiel was accomplished

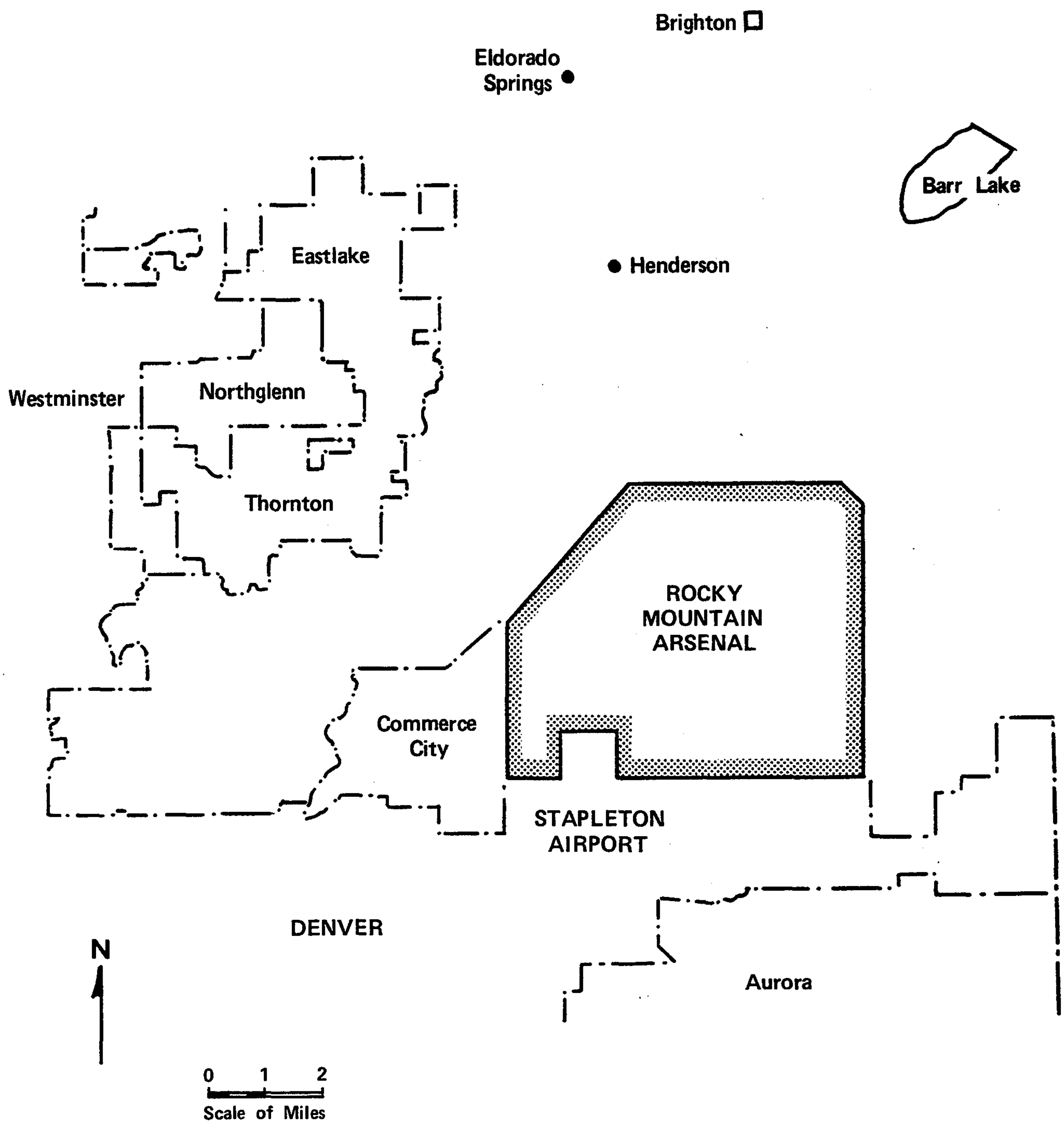


Figure 1. MAP OF RMA – DENVER VICINITY

by sea burial, controlled detonation and incineration. Additional requirements for disposal operations were established in 1970 (PL 91-441, 91-190 (NEPA)). Since 1970, the several major disposal actions have been safely completed meeting the requirements of all Public Laws. Actions taking place at RMA have been the following:

(1) In September 1972, incineration of anti-crop agent TX stored in 12 gallon drums was completed.

(2) During the period 1972-1974, the mustard agent in 3,407 ton containers was destroyed by incineration.

(3) During the period 1973-1976, 21,114 GB agent-filled M34 cluster bombs were demilitarized. The GB agent was drained from the munitions and destroyed by caustic neutralization. The explosive components were destroyed by incineration.

(4) In November 1974, approximately 43,000 gallons of GB agent were drained from underground tanks and destroyed by caustic neutralization.

(5) During 1975, approximately 428,000 gallons of GB agent were drained from 2,422 ton containers and destroyed by caustic neutralization.

(6) In 1976, approximately 9,600 gallons of GB agent were drained from M139 bomblets and destroyed by caustic neutralization. The explosive components were destroyed by incineration.

(7) During the period 1976-1977, 1,294 ton containers of Carbonyl Chloride, which have been sold, are being transferred to an industrial buyer.

3. Waste Basins

Industrial waste effluents generated at RMA have been discharged into a basin just north of the original plant area, referred to as Basin A. This basin received the industrial wastes discharged from all operating plants of the Government and lessees. When the GB Facility was constructed, Basin A was enlarged to accommodate the additional quantity of wastes generated. It soon became evident that additional capacity was required, consequently, new holding basins were constructed northwest of Basin A. The location of the waste basins as well as other features of RMA are shown in Figure 2.

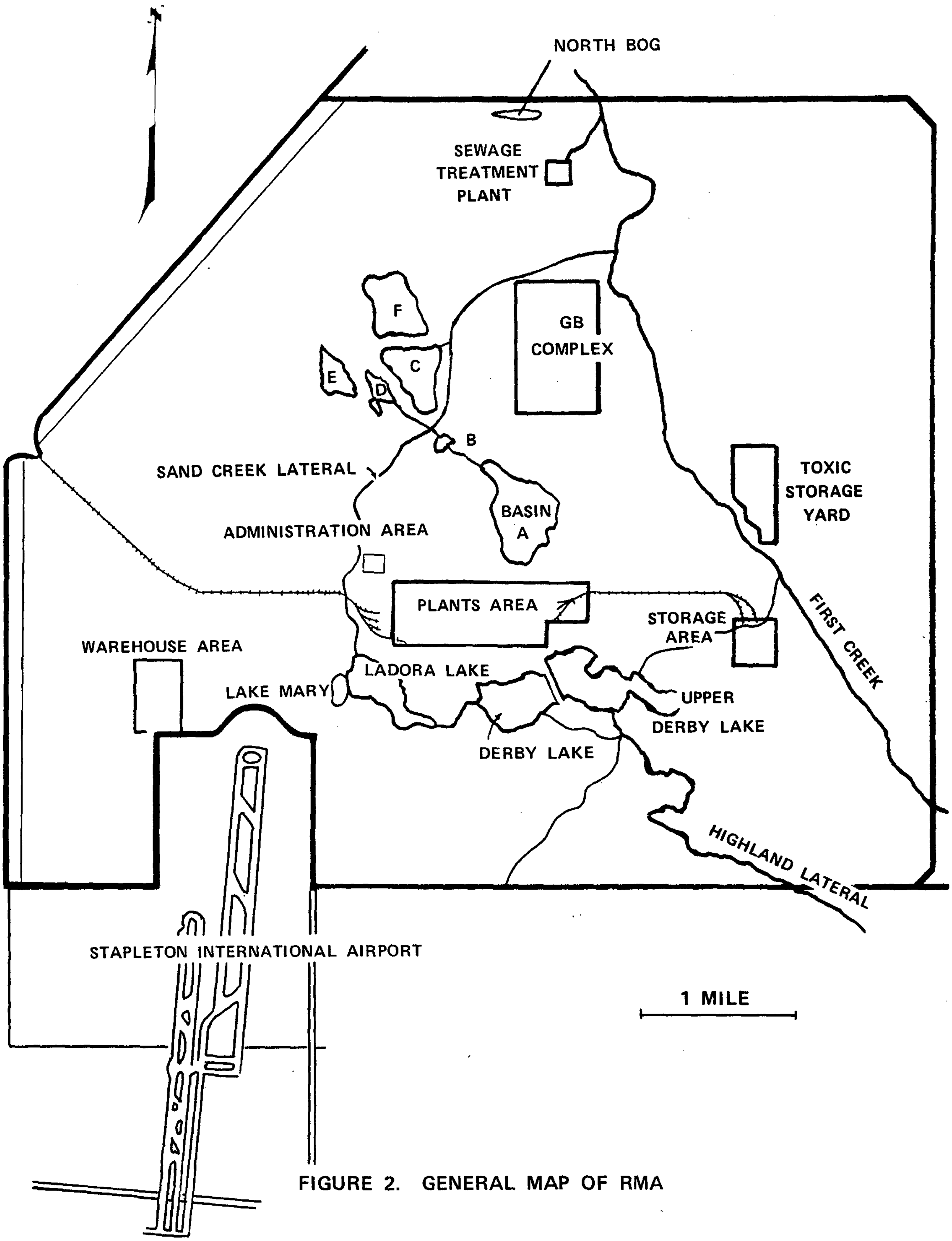


FIGURE 2. GENERAL MAP OF RMA

4. First Signs of Contamination

a. In the summer of 1954, several farmers complained that ground water used for irrigation had damaged their crops. (The precipitation in 1954 was considerably below average, and increased pumping from shallow irrigation wells was required to produce crops.) Due to the increase of complaints and subsequent claims for damage, the Department of the Army did:

(1) Retain a firm of consulting engineers to investigate the problem of ground-water contamination.

(2) Request the US Geological Survey to study water quality on the Arsenal and on neighboring farmlands.

(3) Contract the University of Colorado to undertake plant bioassay, chemical, and geological studies to determine the identity and source of contaminants causing crop damage.

b. As a result of these actions, Reservoir F was constructed. The reservoir was lined and sealed by laying a catalytic air-blown asphalt membrane over the surface and then protecting the membrane by covering it with a foot of soil. When Reservoir F was completed in early 1957, all industrial wastes being generated on the Arsenal were diverted to the new reservoir.

5. Deep Well Disposal

In a short time, it became apparent that Reservoir F was inadequate for the volume of liquid waste being generated by Arsenal activities. A comprehensive study resulted in the decision to provide a Deep Well Disposal Facility for RMA under the construction responsibility of the Corps of Engineers. The well was drilled to the basement complex at a depth of 12,045 feet. This facility began operation in Jan 62, and was shut down in Feb 66. This was done because new information indicated such activity could cause, and may have been causing, the earth tremors which occurred in the Denver area during that time frame. Reservoir F was again used for disposal.

6. Related Legal Decisions and Current Actions

a. In May 1974, diisopropylemethylphosphonate (DIMP) and dicyclopentadiene (DCPD) were detected in surface water draining from a marshy bog on the northern boundary of the Arsenal. DIMP is a persistent compound

produced in small quantities (less than three percent) during the manufacture of GB. DCPD is a chemical used in the production of pesticides. These compounds are described in Inclosures 1 and 2 to Appendix A. Detection of these two compounds resulted in the following actions:

(1) The Arsenal ground water well-monitoring program was expanded. Tests for DIMP and DCPD as well as other compounds were included. These tests are discussed in Appendix A.

(2) In September 1974, a dike was constructed north of the marshy bog eliminating off-post surface drainage.

(3) RMA and Ft. Detrick conducted studies to determine the effect of DIMP on wheat growth. These studies, discussed in Appendix A, indicate that DIMP does not effect wheat growth when introduced at concentrations similar to those found in ground water at RMA.

b. In December 1974, the Colorado Department of Health detected DIMP in a well near the city of Brighton. Although the quantity of DIMP detected was extremely small (0.57 parts per billion), it indicates that ground water may travel in a northerly direction. A two-year study by USGS tends to confirm this direction of ground water flow.

c. The detection of DIMP and DCPD in surface water off the Arsenal and DIMP in wells near Brighton led to the issuance of three Cease and Decist Orders on 7 Apr 75 by the Colorado Department of Health (Appendix B). In short, these orders stated that SCC and RMA must:

(1) Immediately stop the off-post discharge (both surface and subsurface) of DIMP and DCPD.

(2) Take action to preclude future off-post discharge (both surface and subsurface) of DIMP and DCPD.

(3) Provide written notice of compliance with item (1).

(4) Submit a proposed plan to meet the requirements of item (2).

(5) Develop and institute a surveillance plan to verify compliance with items (1) and (2).

7. Development of Installation Restoration Program

a. As a result of the Cease and Desist Orders, as well as the Army's recognition that contamination and contaminant migration has resulted from past pollution, a program of installation restoration was established and placed under the direction of the Project Manager for Chemical Demilitarization and Installation Restoration (PM CDIR). The objective at RMA is to contain contaminants which are migrating from the Arsenal, both surface and subsurface. Contaminated land areas will be restored when they are identified as sources of off-post contamination.

b. Environmental Setting

Rocky Mountain Arsenal (RMA) is east of the Rocky Mountains and is characterized by low rolling topography. The average elevation across the Arsenal is 5,250 feet above mean sea level. The topographic relief across the Arsenal is approximately 200 feet, and the land surface generally slopes northwest toward the South Platte River.

1. Geology

a. The Denver-Arapahoe formation forms the bedrock structure under the Denver-RMA area. This formation is characterized by gray, brown, tan, and greenish-gray shales, clays, and siltstones, with numerous beds of light-colored conglomerate and sandstone. Its thickness varies but averages about 400 feet under RMA. Water wells usually yield less than 25 gallons per minute for this formation. The water quality is variable and locally may contain high concentrations of dissolved solids, iron, and hydrogen sulfide gas. The bedrock surface has been extensively eroded in the past.

b. In the vicinity of RMA, the bedrock is overlain by alluvial material composed of a reddish brown silty clay, silt, sand, and gravel lenses. This sediment is overlain by wind-deposited silts and sands. This wind-deposited material is the surface sediment, except in the vicinity of the southern lakes and First Creek, where alluvial clays, silts, sands and gravels predominate.

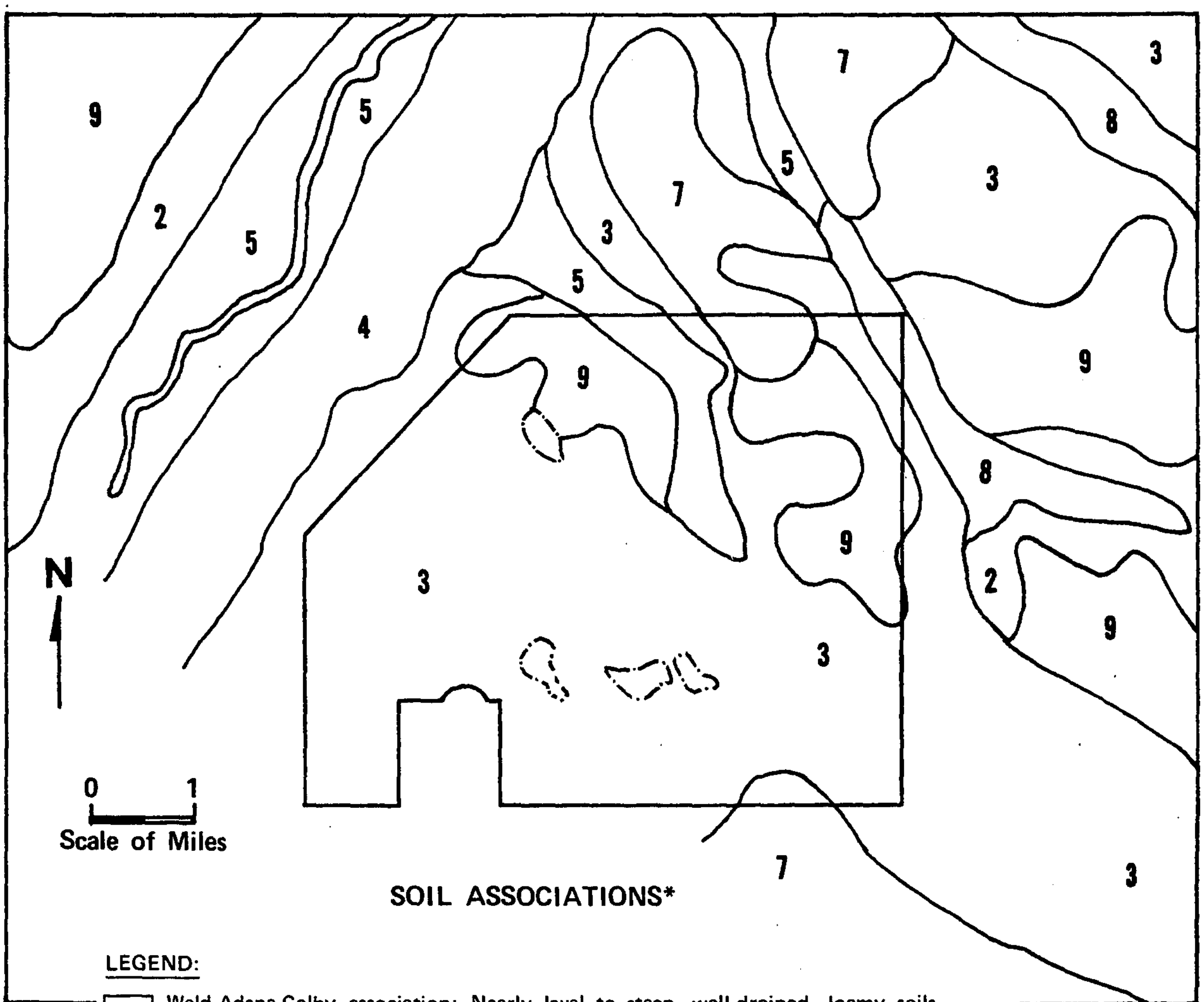
c. A soil survey of Adams County, Colorado, has been completed by the US Department of Agriculture, Soil Conservation Service, in cooperation with the Colorado Agricultural Experiment Station. The portion of the Adams County general soil map, including RMA, is shown in Figure 3. The map shows that the predominant soil association on RMA is the Ascalon-Vona-Truckton. Along the northern part of the Arsenal, an alluvial land association and the Platner-Ulm-Renohill Association occurs. These latter associations roughly correspond to the First Creek channel and adjoining uplands.

2. Subsurface Water Flow Pattern

a. The ground-water table aquifer in the vicinity of the Arsenal is contained in the saturated sediment bounded by the bedrock structure (Denver-Arapahoe formation) and the land surface. The present bedrock surface represents an erosional land surface that was sculptured by fluvial erosion processes. These processes resulted in the evolution of an extensive drainage system as shown in Figure 4. The arrowed lines approximate the original drainage system and direction of flow. Subsequent geological processes buried the original drainage system with a mantle of alluvial and eolian sediment. During this covering period, surface drainage was maintained and generally conformed with the original drainage network.

b. A contour map of the RMA area ground-water system was constructed by the US Geological Survey and is shown in Figure 5. From this map, the main ground-water flow pattern can be reconstructed by drawing flow lines perpendicular to the contour lines with flow direction toward the lower elevation contour lines. The general direction of ground-water flow through the Arsenal is southeast to northwest.

c. The water table aquifer at the north boundary of RMA is of primary concern in this phase of the Installation Restoration (IR) Program. Past Army actions have affected ground-water quality. Two compounds identified in the ground water by State of Colorado Cease and Desist Orders are DIMP and DCPD. Of these compounds, DIMP is the most persistent and the concentrations shown in Figure 6 have been measured in bore holes drilled at the north boundary of RMA. The logs of these bore holes were used to construct the east-west cross section shown in Figure 7. The ground-water flow is primarily in the sand and gravel strata (marked SP & SP-GP). The silt and clay strata, although saturated, has such low permeability that very little flow occurs. This portion of the



SOIL ASSOCIATIONS*

LEGEND:

- **1** Weld-Adena-Colby association: Nearly level to steep, well-drained, loamy soils formed in wind-laid deposits; on uplands
- **2** Samsil-Shingle association: Sloping to steep, excessively drained, clayey and loamy soils formed in materials from soft shale and sandstone; on uplands
- **3** Ascalon-Vona-Truckton association: Nearly level to strongly sloping, well-drained and somewhat excessively drained, loamy and sandy soils formed in wind-laid deposits; on uplands
- **4** Nunn-Satanta association: Nearly level, well-drained, loamy soils formed in alluvial materials that are underlain by gravel in some places; on terraces and fans
- **5** Alluvial land association: Nearly level, poorly drained to well-drained, loamy and sandy soils formed in stream and river deposits; on flood plains
- **6** Terry-Renohill-Tassel association: Gently sloping to steep, well-drained and somewhat excessively drained, loamy soils formed in materials from soft sandstone and shale; on uplands
- **7** Blakeland-Valent-Terry association: Undulating to hilly, somewhat excessively drained, dominantly sandy soils; on uplands
- **8** Arvada-Heldt-Nunn association: Nearly level, well drained, loamy and clayey soils formed in alluvium; on terraces and fans
- **9** Platner-Ulm-Renohill association: Nearly level to strongly sloping, well-drained, loamy soils formed in old alluvium on interbedded shale and sandstone; on uplands

*Texture refers to the surface layer of the major soils unless otherwise stated.

FIGURE 3 - GENERAL SOIL MAP

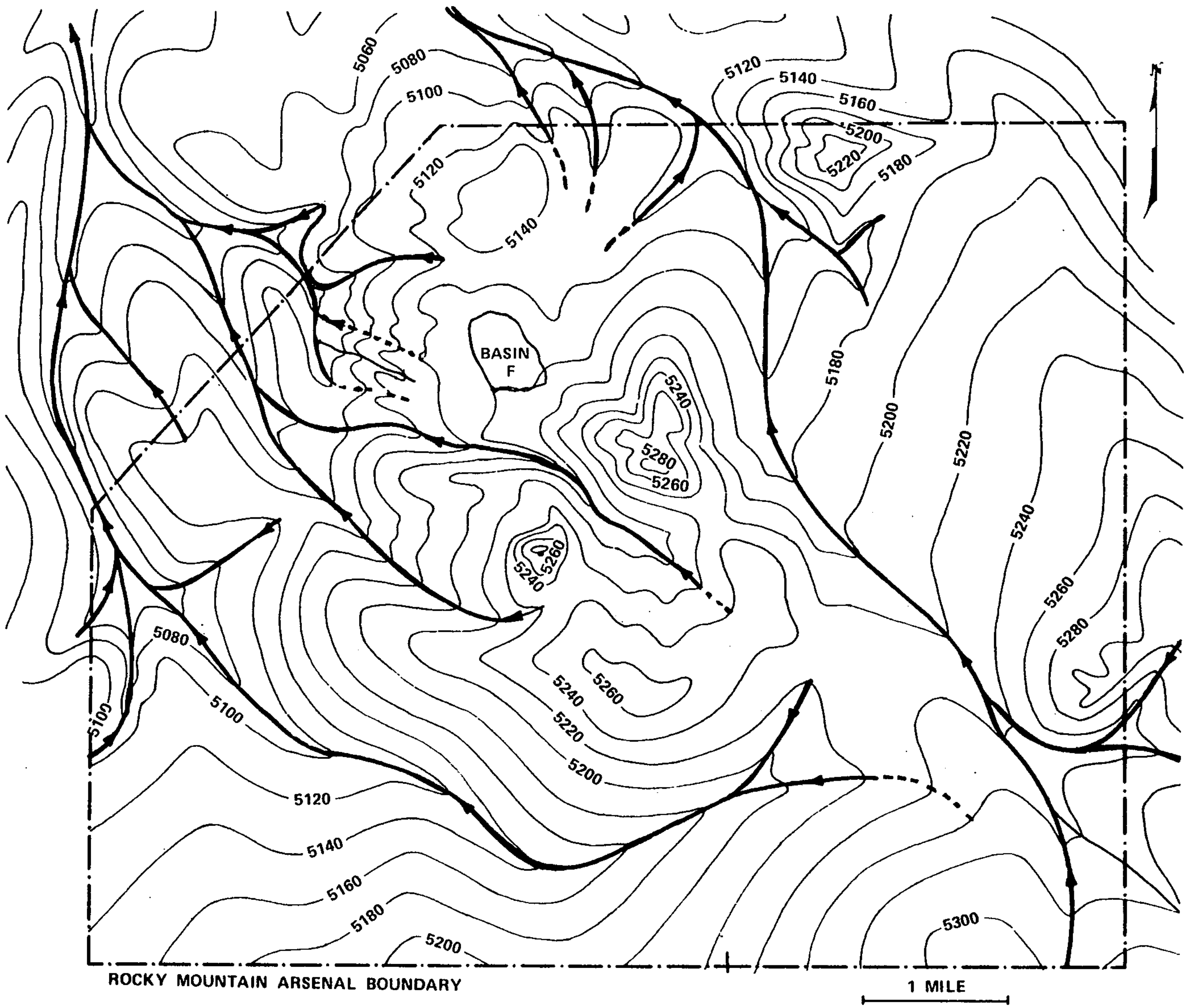


FIGURE 4 BEDROCK CONTOUR MAP

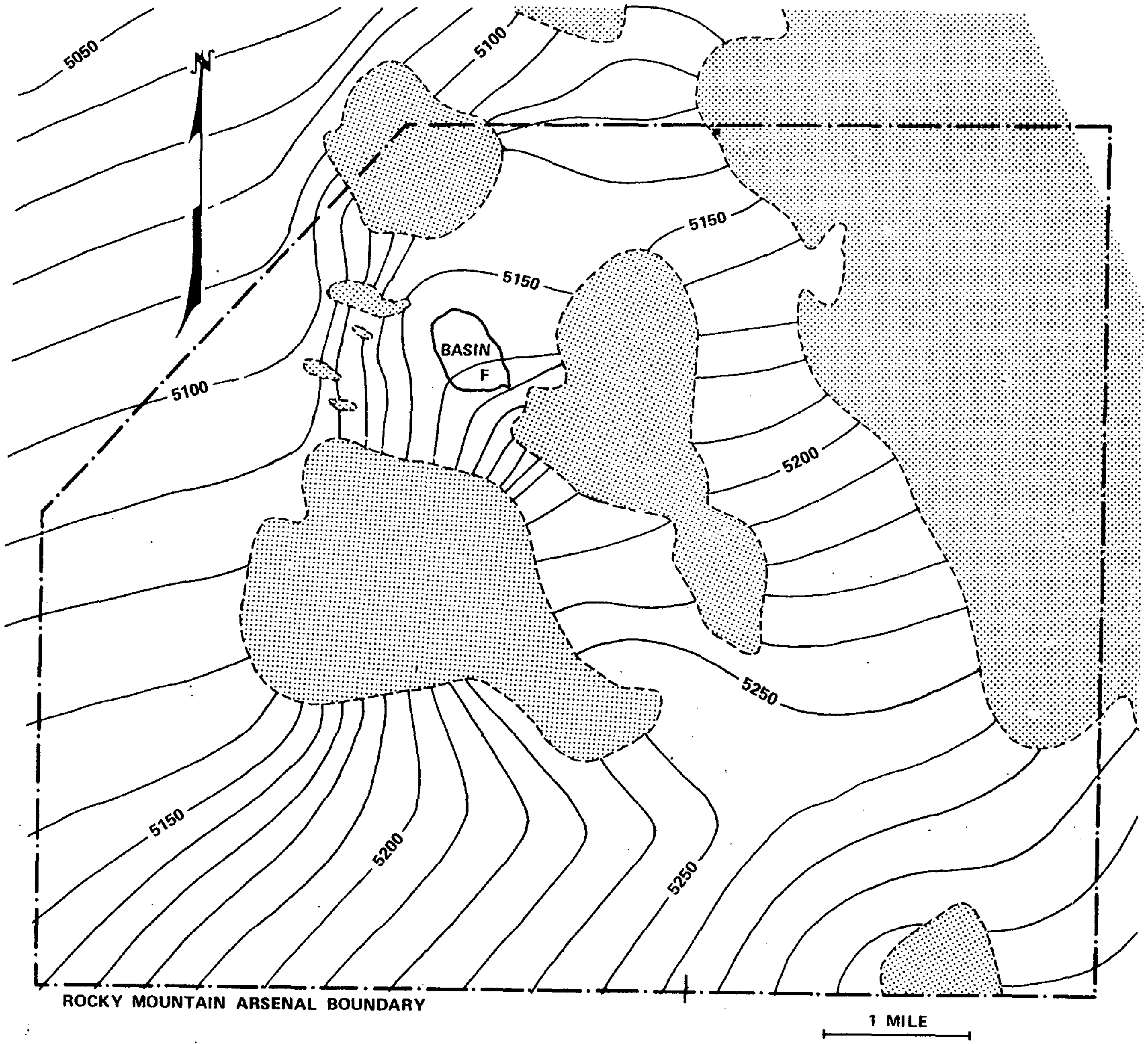


FIGURE 5 GROUND WATER CONTOUR MAP

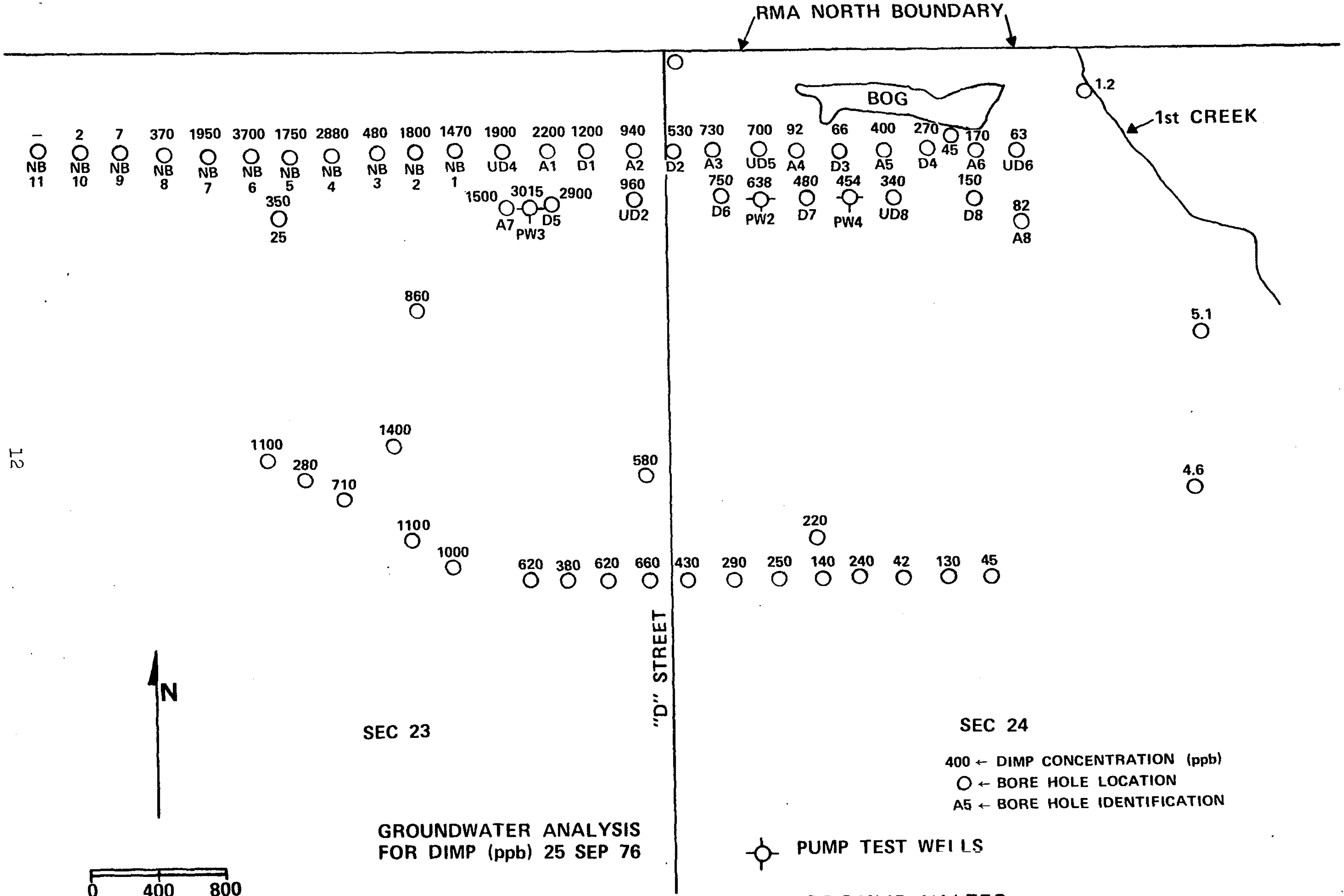
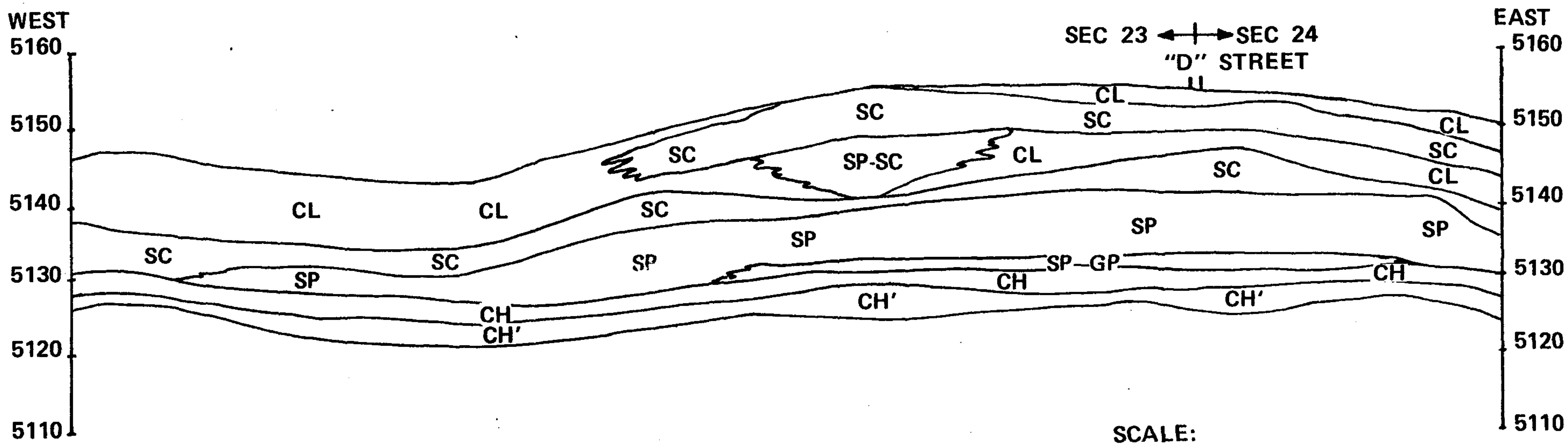


FIGURE 6. DIMP CONCENTRATION IN GROUND WATER



CL — CLAY WITH SILT AND SAND LOW PLASTIC.

SC — SAND WITH CLAY AND SILT

SP — SANDS – POORLY GRADED

SP / GP — SAND, GRAVELLY SAND, SAND AND GRAVEL, POORLY GRADED

CH — MUDSTONE, YELLOW BROWN, HIGH PLASTICITY–BEDROCK

CH' — MUDSTONE, YELLOW BROWN TO GRAY, HIGH PLASTICITY BEDROCK

GROUND WATER FLOW PRIMARILY IN STRATA MARKED SP AND SP–GP

FIG. 7. EAST/WEST SECTION AT NORTH BOUNDARY OF RMA SEC. 23 & 24

aquifer was pump tested at the locations shown in Figure 6. The measured permeability was 200 feet per day in the sand and gravel aquifer. The polluted aquifer flow across the northern boundary is estimated at 10,000 to 25,000 gallons per hour.

3. Surface Water Flow Pattern

a. Infiltrating surface water recharges the ground-water system and, at times, the ground water comes to the surface. Ground water emerges as surface water (see Figure 2) in the north bog, and intermittently along First Creek and in Basins A and B.

b. Surface water flow (Figure 2) is generally to the northwest and is intermittent, occurring mostly after heavy rain. First Creek, the only natural surface drainage system that flows through RMA, originates southeast of the Arsenal and discharges into O'Brian Canal north of the Arsenal. Sand Creek Lateral drains surface water from the south central part of the Arsenal and discharges into Basin C or First Creek, depending on the position of two sluice gates installed at the northeast corner of Basin C. Highland Lateral provides recharge water for the Derby Lakes, Lake Ladora, and Lake Mary. The elevation of these lakes decreases to the west and overflows in that direction. Upper Derby Lake overflows to the northeast into First Creek.

c. Basins A, B, D and E are natural depressions dammed to increased capacity. Basin elevations decrease to the northwest. Sluice gates are installed on the overflow side of Basins B and D to regulate the amount of overflow. A sluice gate in the southwest corner of Basin C can control Basin C overflow into Basin D.

4. Climate

a. Spring is the wettest, cloudiest, and windiest season. Approximately 39 percent of the total annual precipitation (normal = 15.51 inches) occurs in spring. Much of this moisture falls as snow during the colder, earlier period of the season. Stormy periods are often interspersed by stretches of mild sunny weather that removes snow cover.

b. Summer precipitation (about 31 percent of the annual total), particularly in July and August, comes mainly from scattered local thunderstorms during the afternoons and evenings. Mornings are usually clear and sunny; however, clouds often form during early afternoon and cut off the sunshine at what would otherwise be the hottest part of the day. Many afternoons have a cooling shower.

c. Autumn is the most pleasant season. Local summer thunderstorms have subsided and invasions of cold air and severe weather are infrequent. There is less cloudiness and a greater percentage of sunshine than at any other time of the year. Precipitation amounts to about 19 percent of the annual total.

d. Winter has the least precipitation accumulation, only about 11 percent of the annual total, and almost all of it is snow. Precipitation frequency, however, is higher than in autumn. There is more cloudiness, and the relative humidity averages higher than in the autumn. Weather can be quite severe but as a general rule the severity is of short duration.

e. Temperature and precipitation normals, means, and extremes are summarized in Table 1. These tabled data, together with the narrative summary above, are the latest information available from the National Oceanic and Atmospheric Administration for the Denver area. The tabled data were collected at the Weather Bureau Office at Stapleton International Airport which borders a part of the RMA south boundary (see Figure 1).

5. Ambient Air Quality - Air monitoring in support of chemical demilitarization at RMA was begun in Oct 69 with the installation of a nine-station ambient network by the US Army Environmental Hygiene Agency (USAEHA). Sampling was initiated for sulfur dioxide (SO_2), nitrogen dioxide (NO_2), acid mist (HCL), and suspended particulates. In addition, oxidants (O_3), wind direction, and wind speed were also sampled at each station. This information has established a baseline from which the Army can determine the degree of pollution, if any, resulting from plant operations. Reviews of the data gathered by USAEHA indicate that the existing air quality in and around the Arsenal is excellent. No significant levels of pollutants have been traced to Arsenal sources. However, occasionally, pollutants in significant amounts have been traced to outside sources, which might be expected since RMA is adjacent to a large metropolitan area. This air monitoring network will be shut down after completion of chemical demilitarization activities at RMA.

6. Ambient Water Quality

a. The sanitary sewage-disposal plant on the north side of the Arsenal processes domestic wastes from RMA and its tenant activities. The treatment plant consists of two Imhoff tanks, a sludge pit, and a lagoon. Influent to the plant is approximately 100,000 gallons per day. Flow through the plant goes to the Imhoff tank and then to the sewage lagoon. From the lagoon, the water overflows into a ditch which discharges into First Creek, and then travels along the creek about 0.3 miles before leaving the Arsenal at the north boundary. The effluent from the plant meets the existing state standards for reduction of biochemical oxygen demand (BOD); however, control of pH in the sewage lagoon is an occasional problem.

TABLE 1. TEMPERATURE AND PRECIPITATION NORMALS, MEANS, AND EXTREMES RECORDED AT STAPLETON INTERNATIONAL AIRPORT

	Temperatures °F				Precipitation in Inches		
Month	Normal Daily Max	Normal Daily Min	Record Highest	Record Lowest	Normal Monthly	Max Monthly	Mean Monthly Snow
January	43.5	16.2	69	-25	0.61	1.44	8.2
February	46.2	19.4	76	-18	0.67	1.66	7.9
March	50.1	23.8	84	- 4	1.21	2.89	12.7
April	61.0	33.9	84	- 2	1.93	4.17	9.9
May	70.3	43.6	93	26	2.64	7.31	1.6
June	80.1	51.9	98	36	1.93	4.69	Trace
July	87.4	58.6	103	43	1.78	6.41	0.0
August	85.8	57.4	100	41	1.29	4.47	0.0
September	77.7	47.8	97	20	1.13	4.67	1.8
October	66.8	37.2	87	3	1.13	4.17	3.7
November	53.3	25.4	78	- 2	0.76	2.97	7.9
December	46.2	18.9	73	-18	0.43	2.84	6.4
YEAR	64.0	36.2	103	-25	15.51	7.31	60.1

b. Another area of continuing concern is the industrial lakes (Ladora, Lower Derby, and Upper Derby) which supply process water to SCC. Although these fresh water lakes are generally pollution-free and support a variety of waterfowl, fish, and other aquatic life, incidents of accidental spillage of insecticides (especially aldrin and dieldrin) from Shell's operation have occurred in the past. Although water samples from the lakes lack evidence of contamination, analysis of aquatic life shows that fish still retain significant insecticide levels.

c. Contamination of ground water and surface water from wastes discharged by Army and tenant activities is a problem at RMA and the major reason for the IR program. As a result of the IR program, the degree and extent of this contamination will be determined. This EIS describes the second step to be taken, the treatment of contaminated ground water leaving RMA.

7. Ambient Noise - Sources of noise at RMA are two large industrial facilities on the Arsenal. Compared to open unpopulated areas of RMA, noise levels are relatively high in these facilities due to industrial operations. The major portion of RMA, however, would normally experience quite low noise levels except in the proximity of Denver's Stapleton International Airport. The major north-south runway of the Airport was recently expanded so that it extends more than a mile past the southern boundary into the Arsenal. Ambient noise along the flight paths to this runway (and over much of RMA) is high during take-offs and landings.

8. Socio-economic Factors

a. The land use surrounding RMA is diverse. The northern and eastern borders are primarily bounded by agricultural lands. Adjacent to the southern border lies an industrial area, Stapleton International Airport, a housing development, and agricultural land. Along the western border is a residential area, a part of Commerce City, a suburb of Denver. Figure 8 is a general land use map of the RMA area.

b. Rocky Mountain Arsenal has a total authorized strength of 58 military and 873 civilian personnel. The Installation Restoration program at RMA has an authorized strength of 65 civilian personnel. The actions described in this EIS are part of the IR program and will not affect the current strength authorized the program at RMA.

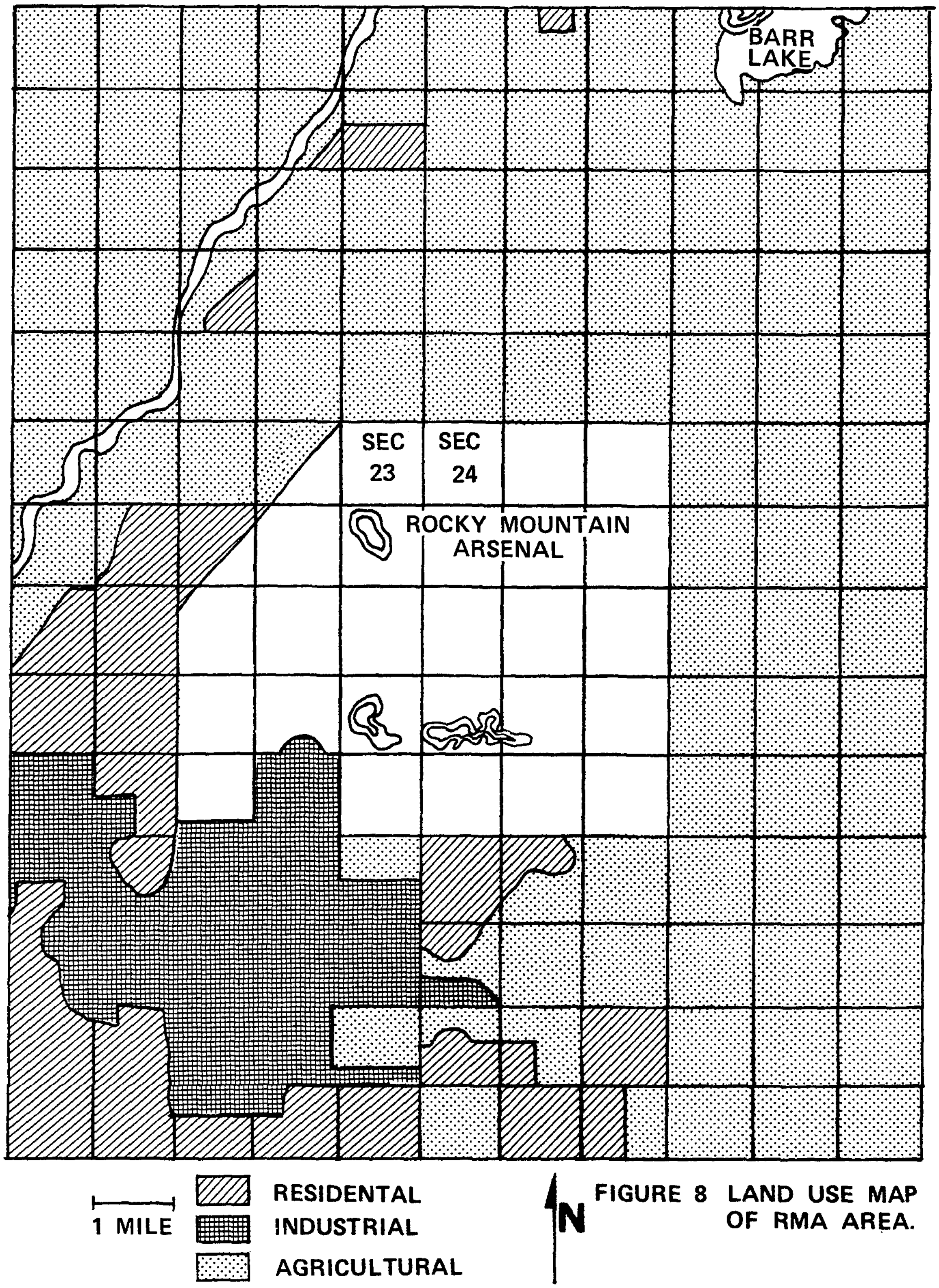


FIGURE 8 LAND USE MAP OF RMA AREA.

9. <u>Fauna and Flora</u>

a. Originally, RMA was covered with shortgrass prairie unique to the prairie regions of North America. Settlement (beginning around 1860) caused drastic changes in the shortgrass prairie ecosystem.

b. Prior to RMA's establishment, the property was chiefly used for agricultural purposes. In addition to the crop fields and remnants of native prairie, clumps of planted trees and shrubs associated with the farmsteads were scattered over the area. Since that time, although much of the land has not been modified, a number of factors have worked to change the character of the land even further. Approximately 800 acres of RMA are now dedicated to industrial, commercial, and residential uses. During the 1940's a portion of RMA was leased for agricultural purposes. In addition, crops such as wheat and corn have been planted on RMA for game habitat improvement. A large area in the northern portion of the Arsenal was planted with wheat for the production of biological agents during the 1960's. During the late 1960's, over 2,800 acres were leased for cattle grazing. Over the years, large disturbed areas and roadsides have been planted with crested wheatgrass for soil stabilization purposes. In addition, trees and shrubs have been planted around buildings and along roadsides. Finally, occasional prairie fires have affected the vegetation of small areas.

c. As a result of the above factors, RMA contains a great variety of habitats. These factors, together with the minimum of human disturbance of the past 30 years and the close proximity of a large metropolitan area, have changed RMA into a diverse and unique natural area.

d. Preliminary ecological work has been done in order to describe RMA habitats. The results of this work are presented in Appendix C. Part of the Installation Restoration activity is the complete inventory and monitoring of fauna and flora at RMA. A schedule for this work has been established. Collection of vegetative data and census of birds have been completed. Fish and mammal censuses have been initiated. Work on invertebrates, amphibians, and reptiles is scheduled to begin in the spring of 1977.

e. Of particular interest are species which are considered endangered or near extinction. Concern for certain species of plants has been expressed, but no plants are presently on the endangered species list (see Appendix C). The officially listed fish, amphibians, or reptiles have not been observed in the RMA area. Since they do not normally reside in the habitats found at RMA, their absence is not significant. Several species of endangered, threatened or rare birds have been observed at or near RMA. These are also listed in Appendix C. The only listed mammal which may exist at RMA is the black-footed ferret. However, despite efforts to confirm its presence, there have been no confirmed sitings in the vicinity of RMA since 1914 and none in the state of Colorado since 1946.

10. Area History and Archaeology

a. Prior to the purchase of the land that comprises RMA, the land was settled and homesteaded for small farms and livestock grazing ranches. On inspection of maps, dated 1899 and 1957, there were no significant historical or archeological sites of any importance. No community cemeteries were marked on these maps. A school, "Prairie View School," was marked in the southwest corner of Section 6 on the 1899 map but was not so marked on the 1957 US Geological Survey Topographic map. A geological bench mark was marked on both maps in northwest Section 19 called the "Henderson Bench Mark," and it remains there to this day.

b. The Colorado State Historical Society, Department of Buildings and Sites was contacted concerning any known pioneer cemeteries or other sites of historical importance. It was indicated that the Department was unaware of any such sites on the RMA reservation.

c. The Colorado State Archaeological Office was contacted for any archaeology sites of record. That office searched their files and did not find any recorded archaeological sites. If any archaeological artifacts are found during construction of the pilot system, the Colorado State Archaeological Office will be contacted.

11. Agreements with Other Federal Activities In accordance with the authority contained in Title 10, US Code, Section 2671, approved 15 Sep 60. The Department of Defense, the Department of Interior, and the State of Colorado approved a cooperative plan for the protection, development, and management of fish and wildlife resources on RMA. This plan was approved on 11 September 1963. It is the only major agreement with other Federal activities.

C. Description of Action

The short range objective of the IR Program is to demonstrate compliance with the Cease and Desist Orders. The first step toward compliance was bench-scale studies and ground water studies. This action, installation of a pilot contaminant containment/treatment system, is the second step toward compliance. The third and final step will be the installation and operation of a full-scale contaminant containment system. The later action is anticipated to require additional environmental impact assessment. Data obtained from the operation of the pilot system(s) will be used to select and design the full-scale system. The pilot system consists of a dewatering subsystem, a water treatment subsystem, and a ground-water recharge sub system. These will be installed close to the northern boundary of RMA as shown in Figure 9.

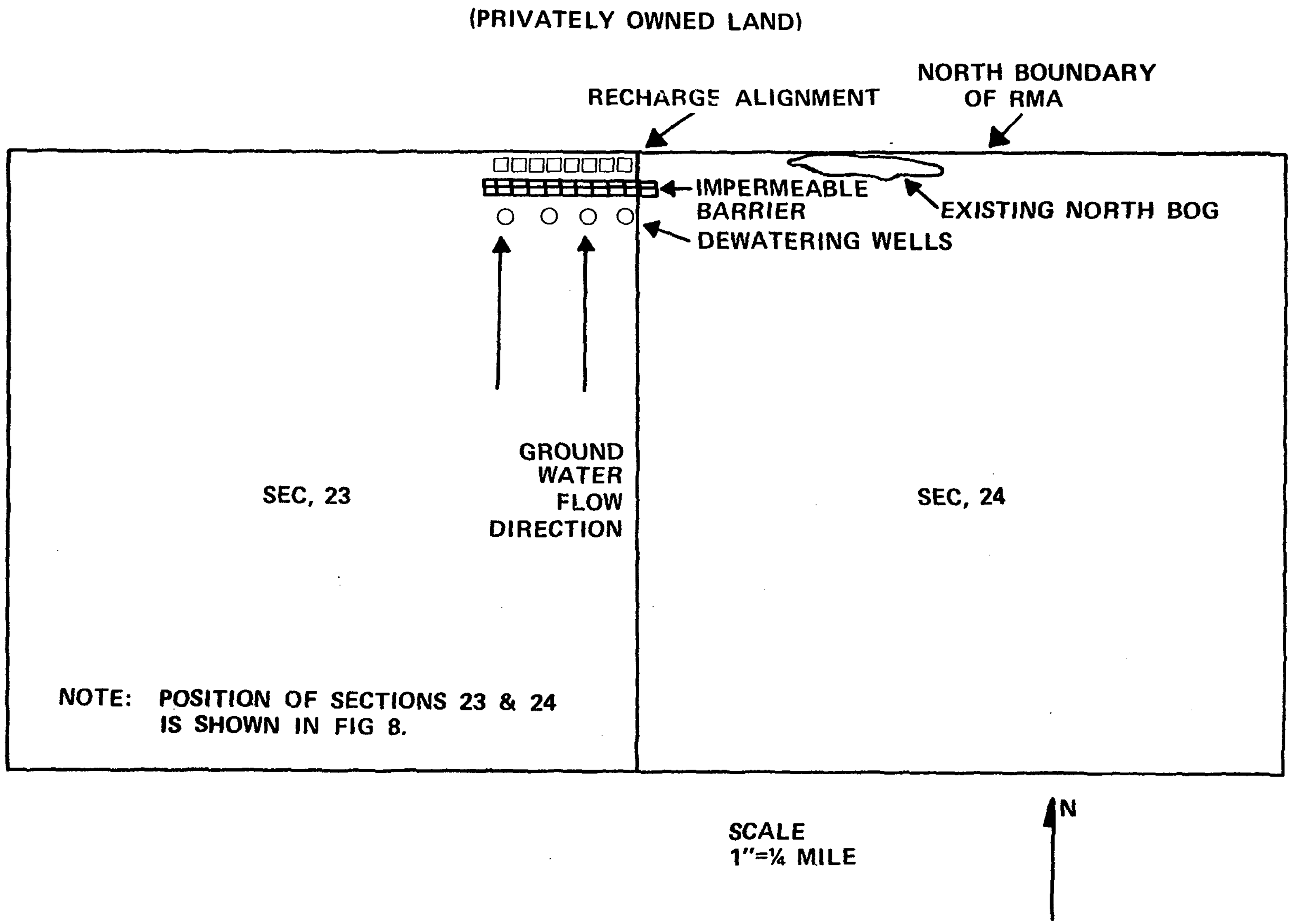


FIG. 9. DEWATERING AND RECHARGE COMPONENT LOCATION MAP

1. Ground-Water Dewatering and Recharge Components.

a. The dewatering and recharge components will be placed in close proximity to one another at the position shown in Figure 9. This position was chosen based on an analysis of mass rate flow of DIMP across the north boundary of RMA. DIMP was chosen as the compound for this analysis because it is the most widespread contaminant and one of the most persistent. This analysis considers DIMP concentration, permeability of the aquifer, permeability of the overlying sand/silt layer, and saturated flow thickness. The analysis was conducted for the entire north boundary and was made for unit slope on the ground-water table. Figure 10 is a graphic representation of the results. As can be seen, the position of the dewatering and recharge components coincides with the area of highest mass rate of contaminant flow.

b. The dewatering component will consist of four to six, eight-inch diameter wells. Each well will be equipped with its own pump and a flow control system. The exact number of wells will be determined at the time of construction. As each well is completed, it will be tested for pumping efficiency. The results of these tests will determine the final well requirements. Data to date (Figures 11 and 12) indicate that four wells would be sufficient to dewater the aquifer without excessive drawdown of the aquifer either at the pump wells or between pump wells. The data in the figures were derived from evaluation of field pumping tests conducted along the north boundary of RMA. The average flow rate per well (assuming a four-well system) would be 2,000-2,500 gallons per hour per well or 8-10,000 gallons per hour over the described alignment. As can be seen in the Figures, the drawdown at each well is expected to be between 5 to 7 feet (depending on aquifer transmissibility) and 2 to 3 feet between pump wells. The completion tests will be used to modify these data, if required, and to determine whether more than four wells are needed to prevent excessive aquifer drawdown at any one point due to individual well failure.

c. These wells will be installed according to accepted practice. All wells will fully penetrate the aquifer and will be cemented in place to prevent surface leakage. All piping associated with the wells will be buried below the frostline to prevent freezing.

d. The recharge component will be a series of infiltration pits. The bottom of the pits will be at the top of the aquifer. The exact number of pits and the size of each pit will be determined during design. The factors influencing size include aquifer characteristics, recharge rate, surface topography, position and thickness of the aquifer, sands and gravel. The present estimate is that 7-9 recharge pits will be required, each pit having a bottom width of approximately 5 x 10 feet. The total length of the recharge alignment will not exceed the length of the dewatering alignment. The influence of recharge on the ground-water system will be minimal because of the relatively large area of the pits. The maximum anticipated rise of the ground water is 1 to 3 feet at the recharge pits. This level will diminish rapidly to natural conditions away from the pits.

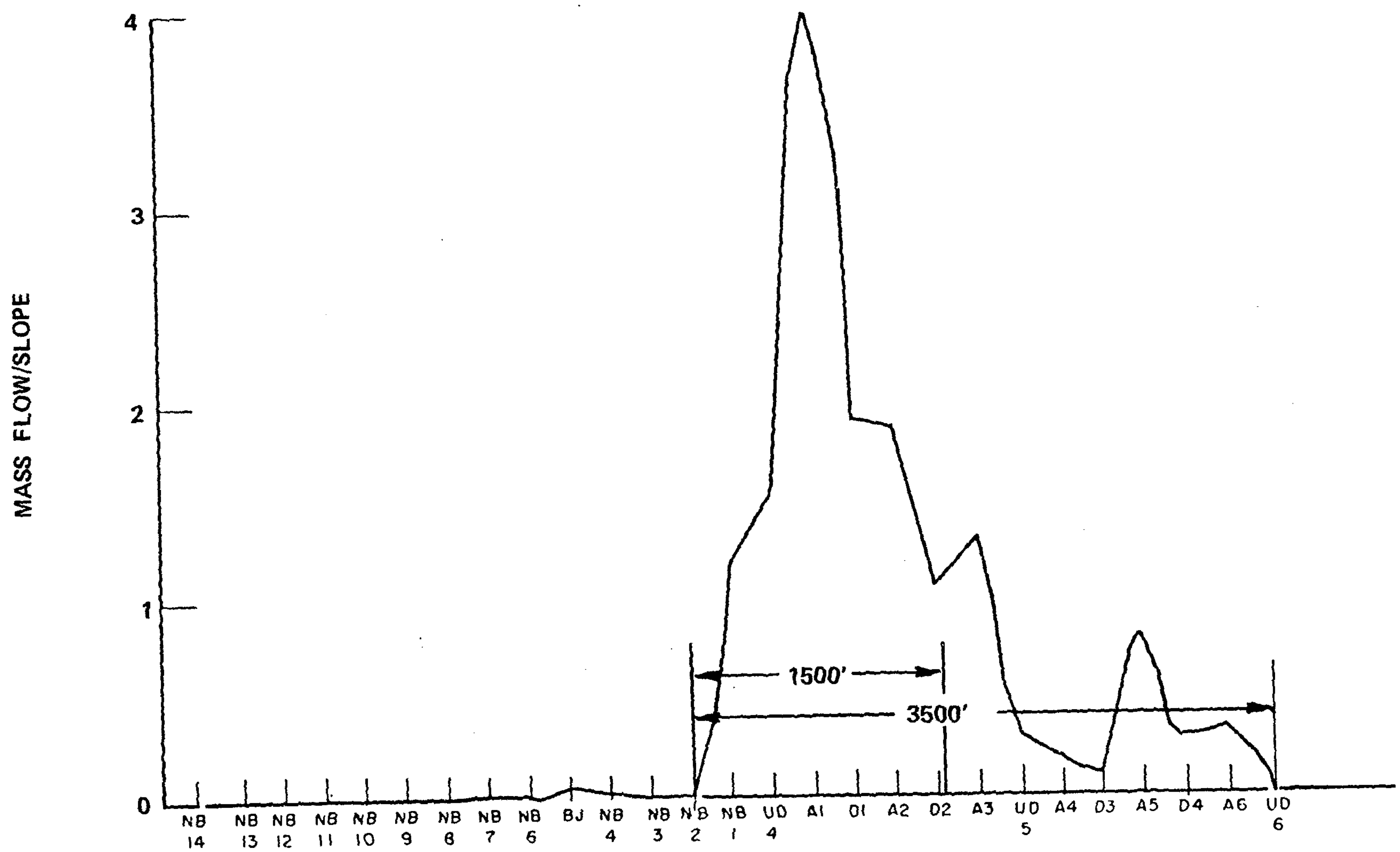


Figure 10. FT^3/DAY—FT/UNIT SLOPE VS WELL NUMBER

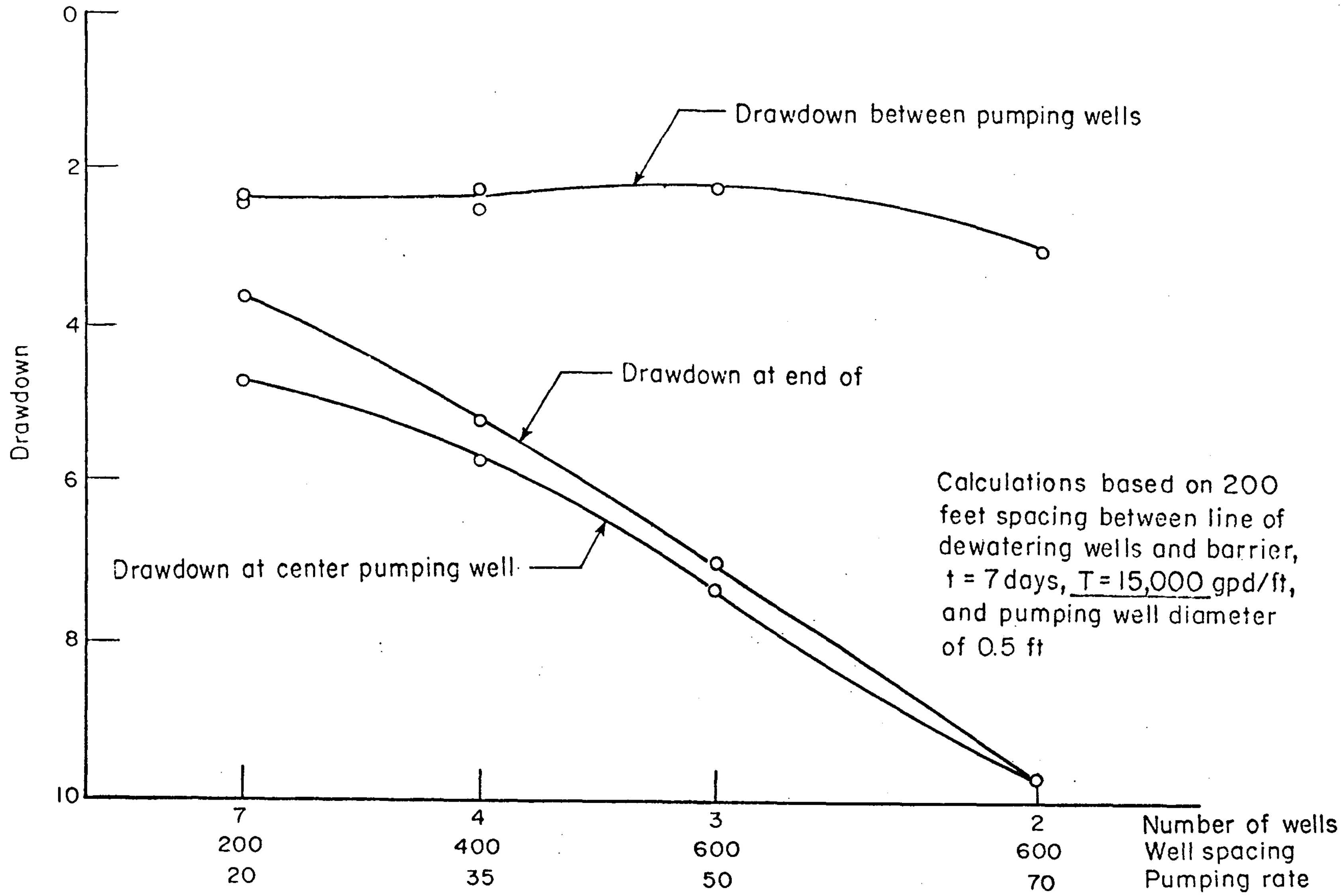


FIGURE 11 DRAWDOWN VS NUMBER OF WELLS
T=15000 $^{gpd}/_{Ft}$

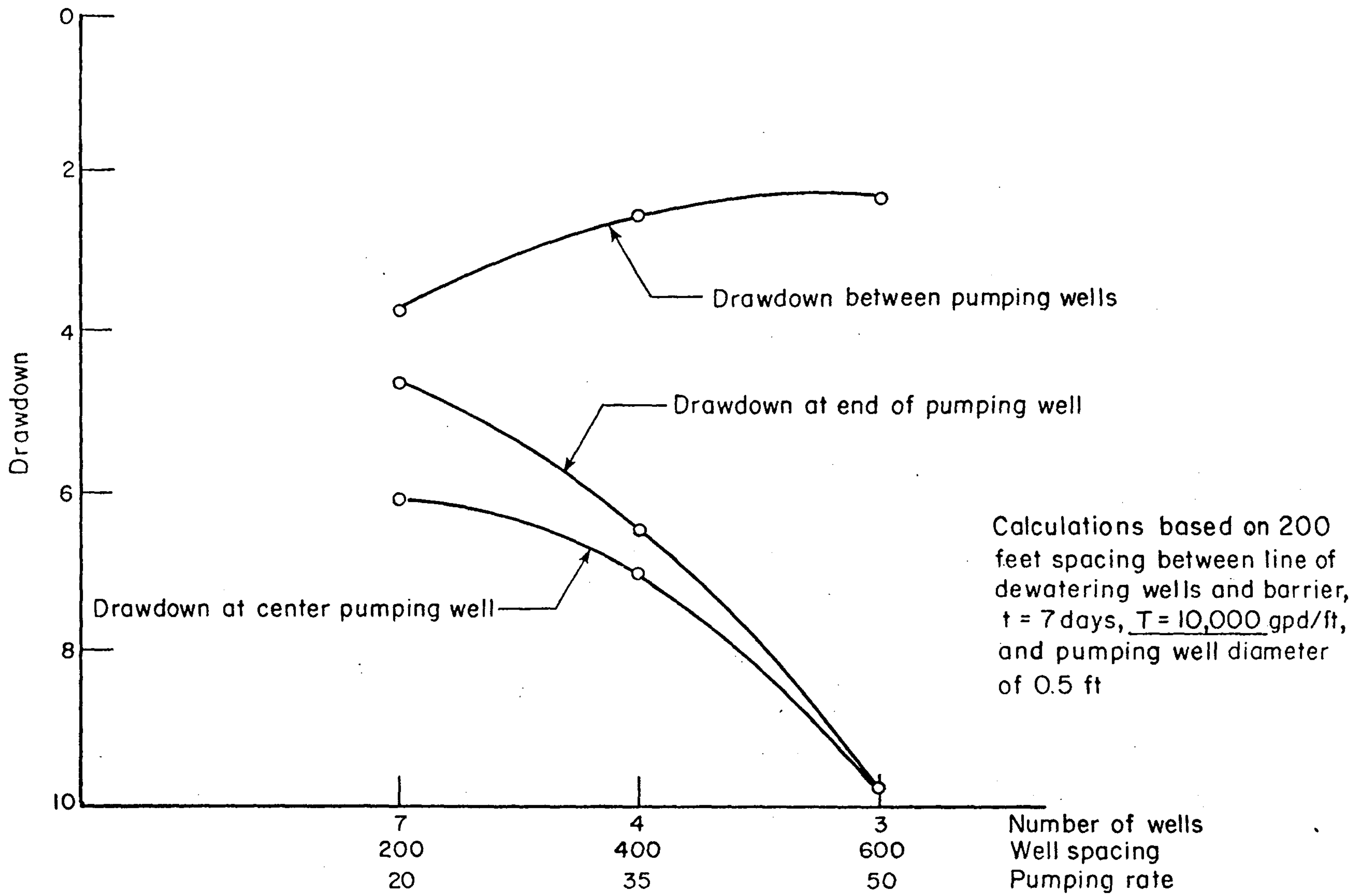


FIGURE 12 DRAWDOWN VS NUMBER OF WELLS
T=10000 gpd/Ft

e. The soil excavated to form the recharge pits will primarily be from the unsaturated zone above the ground-water table. Soil sampling and analysis work done by the Army Surgeon General (Appendix A) has shown that the soil in the area of the recharge component is relatively uncontaminated. Therefore, this excavated soil, approximately 300 cubic yards, will be used around the recharge site as required.

f. The separation between the dewatering and recharge components (Figure 9) will be between 300 to 500 feet. To prevent leakage of contaminated water past the dewatering line, or recirculation of clean water from the recharge ponds to the dewatering wells, an impermeable barrier will be constructed between the components. The barrier will be constructed of bentonite clay and will extend over the entire length of the pilot dewatering and recharge components. The barrier will be approximately 3 feet wide and will extend 25 feet into the clay shale bedrock (23-27 feet). The barrier will be placed according to accepted engineering practice. As the trench is excavated it will be filled with the bentonite slurry. The excavation will continue through the slurry, and the slurry will hold the trench open as the excavation progresses.

g. Some of the soil excavated for the placement of the bentonite barrier may be used as a soil mixture with the bentonite. The unused excavated material will be handled as contaminated material since it was in contact with the polluted ground-water system. The volume of this type of material will not be excessive (4,700 yd^3 maximum). To preclude further soil contamination, however, this soil material will be removed to an area of higher soil contamination Basin A.

h. Monitoring wells will be installed on both the dewatering and recharge sides of the bentonite barrier. These monitoring wells will be cased and cemented in place to prevent surface leakage. The exact placement of these wells will depend upon the final design of the pilot system. The wells will be monitored for ground-water depth and ground-water quality. The described system is a pilot system and its mode of operation will be varied. The response of the ground-water system to these variations will be measured in the monitor wells. Also, seasonal variations in the subsurface system will be measured by these wells and the associated response of the treatment system will be monitored. These data will be significant in the development of a final containment and recharge system for RMA.

i. The length of the dewatering system was picked at 1,400 to 1,700 feet so that 8,000 to 10,000 gph of ground-water flow would be available to the treatment component. A ground-water system has many variables and

can change significantly within short distances. Also, flow conditions can change significantly with time. Therefore, it is estimated that this alignment will permit measurement of these variations and provide valid operational data upon which system expansion can be based.

2. Ground-Water Treatment Component.

a. The treatment component to be used with the described dewatering and recharge components has not as yet been selected. Testing is being done on three treatment units and the most feasible of these units will be installed, consistent with time scheduling. These three units are described below.

b. RMA has obtained a 10,000 GPH ERDLator from the US Army Mobility Research Equipment and Development Command, Ft. Belvoir, VA. Testing of this unit with powdered carbon was conducted to see if it could be used to treat ground water at RMA. Tests show that this treatment unit can effectively remove DIMP, DCPD, and the sulphur compounds.

c. A schematic diagram of the treatment unit is shown in Figure 13. The influent water is fed through an aerator before it flows to the up-flow clarifier unit. At the same time that the water is fed to the clarifier a slurry of powdered carbon and polyelectrolyte is fed to this unit. The carbon coagulates and is maintained as a fluidized bed in the bottom of the clarifier. The water requiring treatment flows up through this bed, into an overflow weir, and is discharged to the filter units. As the water moves through the carbon bed the compounds of concern are removed from the water by adsorption on the carbon. Fresh carbon is continually added to the bed and the spent carbon is removed. Once the spent carbon is removed from the unit, it is partially dewatered. The remaining slurry is fed to a drying lagoon for further natural dewatering. The treated water, after filtering, is fed to the ground-water recharge pond.

d. As stated above, this treatment process has been checked for removal of the identified compounds in the ground water at the north boundary of RMA. The most work has been focused on DIMP and DCPD as these compounds were specifically cited in the State of Colorado Cease and Desist Orders (Appendix B), and were identified much earlier than the sulphur compounds. Repeated tests have shown that DCPD is consistently removed to below detectable limits (less than 10 ppb). DIMP is somewhat harder to remove but operating conditions have been achieved that affect a 95-99% removal rate. Current data shows that these levels of contaminant reduction can be obtained by dosing powdered carbon at a rate of 220 mg/l to 350 mg/l.

10,000 gal/hr ERDLator

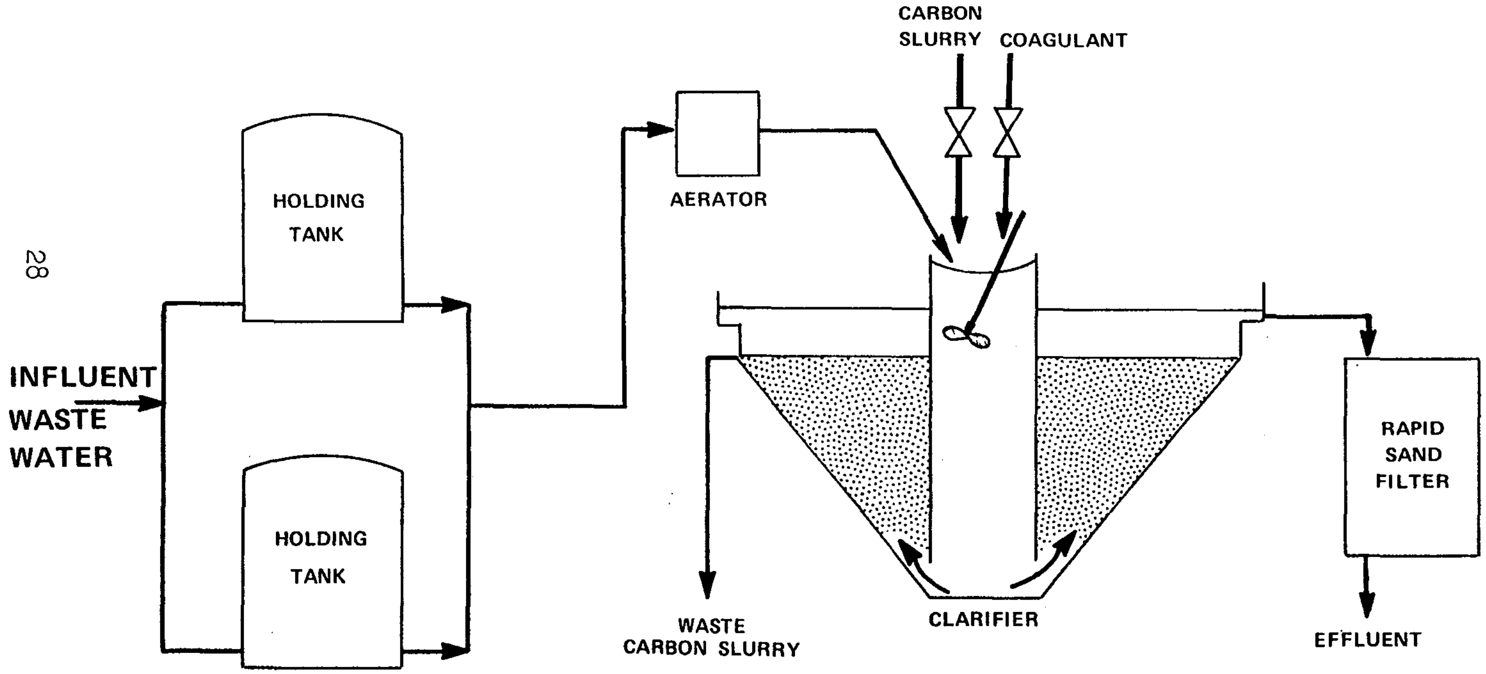


FIG 13 POWDERED CARBON TREATMENT UNIT.

e. A disadvantage of powdered carbon treatment is the disposal of the spent carbon. Powdered carbon is difficult to regenerate; however, industry has recently done some work in this area. To take full advantage of the advances made by industry in powdered carbon regeneration, an industrial practices survey is being conducted to not only evaluate potential regeneration processes but to also determine the most feasible disposal process. This survey will be complete in Apr 77. It is anticipated that the regeneration/disposal of the powdered carbon would be done on contract which would be initiated early in FY 78.

3. Alternative Treatment Systems.

a. The powdered carbon treatment unit discussed above is available for use. Other treatment methods, however, are also being tested to determine whether there are more feasible treatment options. The potential regeneration disadvantage of powdered carbon may be overcome by the use of granular carbon treatment columns are used. Large scale industrial regeneration of spent granular carbon is accepted practice. Therefore, treatability studies using granular carbon columns have been undertaken. This study includes a determination of the potential for regeneration and reuse of the carbon. The studies will be complete by Apr 77.

b. The granular carbon unit concept of operation is basically the same as the powdered carbon unit. As the waste water passes through the carbon pollutants are removed from the water and absorbed on the carbon. Because of the granular nature of the carbon, however, equipment and operations are simplified. Figure 14 is a diagram of a granular carbon treatment unit. The waste water entering the system is first filtered, and then flows through a series of containers (columns) packed with granular carbon. After discharge from the last column, the water is piped to the recharge component. After a period of time the carbon in the columns becomes saturated with pollutants and must be replaced. The number of carbon columns used and the time to carbon replacement are related. Replacement intervals will be determined by the ongoing treatability studies.

c. It is anticipated that the spent granular carbon removed from the treatment unit will be regenerated and reused. The treatability study will determine the feasibility of regeneration. Presently, industrial regeneration appears feasible.

d. The study to date has shown treatment efficiencies for DIMP, using granular carbon, are similar to those using powdered carbon; 95-99% removal. The sulphur compounds are being removed to below detectable limits. This treatability study will be completed in Apr 77.

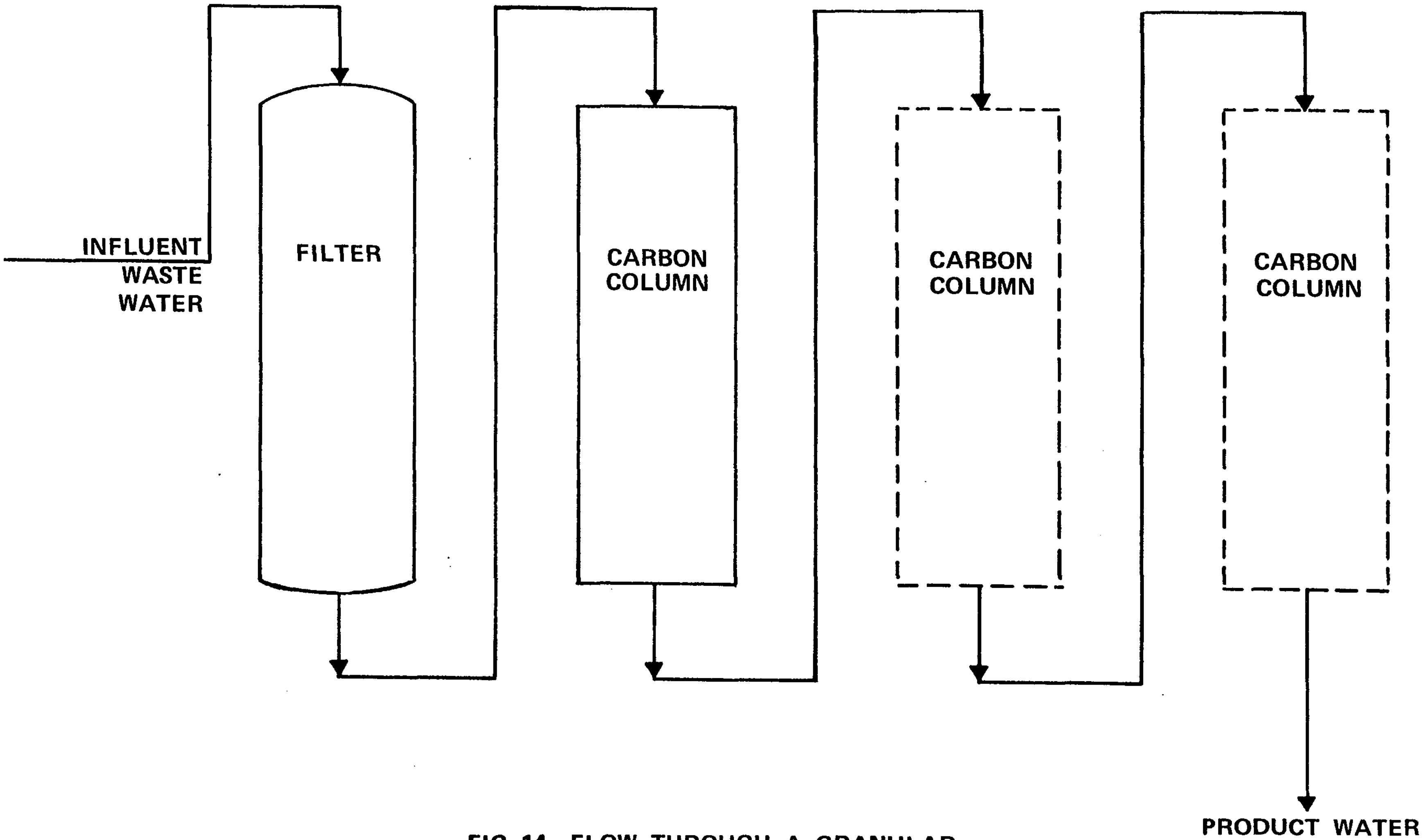


FIG 14 FLOW THROUGH A GRANULAR CARBON SYSTEM

e. The final disposition of process waste, whether granular or powdered carbon, has not been established. After carbon regeneration feasibility studies are completed, disposal and/or regeneration site alternatives will be carefully screened. Whatever the disposal technique employed, an assessment of environmental impact will be made and the findings implemented in such a way as to assure all adverse environmental effects are minimized.

f. Another process being studied is ozone with ultravoilet light treatment (UV-O_3). The advantage of this system is that there are no waste products requiring regeneration or disposal. All pollutants within the waste water are converted by oxidation to innocuous compounds. A brief background on this process and how it theoretically oxidizes DIMP and DCPD is given in Appendix D. The process basically involves feeding the waste water through a reaction chamber where the water is irradiated with ultraviolet light and where the ozone is mixed with the irradiated water. The chamber may be configured with baffles, and similar components to increase the UV irradiation effect and permit better mixing and longer contact time with the ozone.

g. Results to date from UV-O_3 batch reaction tests showed reduction of DIMP from approximately 2.2 ppm to approximately 16 ppb. All other compounds measured were reduced to below detectable limits. Continuous flow-through studies are now being carried out to determine overall treatment efficiencies, retention time requirements, energy requirements, etc.

4. Treatment Process Selection.

a. Current studies will determine which treatment unit will be used with the pilot system. At present, a powdered carbon unit is available at RMA and can be implemented. If, however, one of the alternative methods proves more feasible, it will be implemented. The considerations to be made when evaluating feasibility will include costs (both capital and operating), treatment efficiency, energy requirements, and compatibility of the treatment unit with the total system.

b. Any unit that is implemented will have to insure certain minimum levels of ground-water improvement. These levels have been determined for DIMP and DCPD through the standards development work being carried out by the Army Surgeon General (Appendix A). While the toxicology studies are not yet complete, the Surgeon General has completed enough work

to issue temporary guidelines. These levels are keyed to water use and are listed in Table 2. The ground water effluent from the pilot system must be below the most stringent value, 0.5 ppm, for both DIMP and DCPD. Based on past studies, this value can be achieved with the carbon treatment units.

c. As previously stated, this is a pilot system and operations will be varied to monitor the effects of different system conditions. These variations, however, could cause significant variations in treatment plant influent flow. Consideration will be given to these variations and if a unit buffer is required to keep influent variations from adversely affecting the treatment, it will be installed.

TABLE 2

DIMP AND DCPD

STATUS OF STANDARDS DEVELOPMENT

TEMPORARY GUIDELINE	DIMP (PPM)	DCPD (PPM)
Drinking Water	0.5	1.28
Recreation	5	12.8
Fishing Waters *	6	1.5
Protection of Aquatic Life	12.5	0.5
Irrigation Water	20	20

*NOTE: When human consumption of fish is accepted.

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II. RELATIONSHIP OF THE PROPOSED ACTION TO LAND USE PLANS, POLICIES AND CONTROLS

The proposed action is expected to enhance the quality of the environment and thus conforms with Public Law and Department of the Army regulations addressing environmental policy. The proposed action is consistent with:

a. Department of Defense and Department of the Army land use plans, policies and controls for RMA.

b. Installation restoration program objectives for containing contamination within the boundaries of Federal installations.

c. State of Colorado pollution abatement requirements specified in the Cease and Desist Orders issued against Rocky Mountain Arsenal and Shell Chemical Company (Appendix B).

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III. PROBABLE IMPACT OF THE PROPOSED ACTION ON THE ENVIRONMENT

A. In the short term, localized disruptions of the environment will occur. These disruptions, however, will be minimal and can be assimilated by the existing RMA environment with negligible effect. In the long term, the proposed action will result in a measurable positive environmental effect. The pilot operations described in this EIS will form the base from which final systems can be designed and implemented to enhance the environment. A detailed discussion of environment impact follows.

B. Air Quality - Air quality will be primarily altered by the exhausts from operation of drilling and excavation equipment and any dust raised during these operations. Operation of this equipment will be on an intermittent basis and for relatively short durations. Because of this intermittent operation and the large size of the Arsenal, the exhaust fumes will be naturally dissipated with a negligible effect on air quality. Appropriate dust control measures will be taken.

C. Subsurface Impacts.

1. The ground-water system will be locally disrupted by drilling. The required drilling will be done in accordance with accepted techniques. The localized disruption will be due primarily to disturbance of the aquifer medium and will not result in a change to the quantity or quality of ground-water flow. All exploratory bore holes will be cased and backfilled near the surface to prevent surface runoff from entering the hole.

2. The primary impact on the ground-water system will be due to placement of the ground-water pilot containment and recharge system. This will result in water being removed from the aquifer for treatment. After treatment, the water will be recharged back into the ground-water system. Although the quantity of water in the aquifer will not be affected, the quality will have been improved.

3. Localized disturbances of soil conditions will be caused by placement of the pilot containment system. The placement of the pilot system will result in removal of large quantities of soil. When the impermeable barrier is placed in the ground-water system, the near surface soils will be replaced so that natural surface conditions are restored. All soil removed will be deposited in an area of higher soil contamination (Basin A).

D. Other Environmental Considerations.

1. Noise Levels - Localized increases in noise levels will occur due to operation of equipment, however, operations will not be in close proximity to inhabited dwellings. Personnel will be provided adequate noise protection devices. No increase in the ambient noise level will result from IR operations.

2. Disposition of Contaminated Waste - Disposition of waste carbon or similar wastes resulting from the pilot treatment plant operation is currently under study, and results will be available by April 1977.

3. When this pilot system is no longer required, the bentonite barrier may have to be altered to prevent a serious distortion to the natural ground-water flow. There are several methods of breaching the barrier to insure that it will not have an adverse effect on the ground-water system. The simplest method is to cut through the barrier (for example, with a backhoe) at numerous points along the length of the barrier. The excavated area would be backfilled with gravel and the ground water would flow through the barrier at these select points. These breaches would be sufficiently numerous to insure that the overall ground-water flow is not interrupted. The ground-water collection wells are designed as permanent structures; wells are cemented in place and extraction columns are below the frost line. Wells are capped and could be used at a future date. All operational components of the system would be closed.

E. Ecological Impacts.

1. Vegetation, fish, and wildlife on the Arsenal will be primarily affected by the elimination of some habitats and by increased human disturbance. It is anticipated, however, that these ecological impacts will not be major.

2. The construction of the pilot ground-water containment treatment system will result in the elimination of a certain amount of vegetation, wildlife habitat, and associated wildlife. To minimize the impact of this short-term disruption, the involved area will be reseeded.

3. One to several pairs of short-eared owls generally nest in the tall vegetation of Sections 23 and 24. Although fairly common in winter, this species rarely nests in eastern Colorado. Therefore, special efforts will be made to locate any existing nests and to avoid excessive disturbance or disruption of the nests.

4. The increase of human disturbance in areas of RMA previously subjected to only very light human use will lower, slightly, the quality of wildlife habitat in some areas. Nesting raptors, especially hawks, will be the group primarily affected. Therefore, a special effort will be made to locate all raptor nests each spring and to avoid excessive distrubance or disruption of the nest sites.

5. A discussion of endangered, threatened, or rare species possibly occurring on RMA is provided in Appendix B. It is anticipated that no impacts on these species or their habitats will occur as a result of the proposed actions.

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IV. ALTERNATIVES TO THE PROPOSED ACTION

A. One alternative to the proposed action would be no action. This would result in a continuation of ground-water contaminant flow across the north boundary of RMA. The concentrations of DIMP and DCPD measured in the ground water (at the north boundary) ranges up to 3 ppm. This is in excess of the temporary guidelines recommended by the Army Surgeon General (Table 2, page 30). Existing conditions are such that the contaminated ground water is migrating off RMA, in violation of State of Colorado Cease and Desist Orders. The length of time that these excessive contamination conditions will continue cannot be exactly determined; available data shows that contaminant concentrations exceeding the established guidelines should continue for at least five years. This data takes into account contaminants in the aquifier only, and not the input from contaminant sources. If source input is considered, the flow of contaminants might continue for an indefinite period of time, depending upon source leaching rates.

B. The second alternative would involve no containment at the north boundary but would provide for cleanup of contaminant sources. The work to define these sources has been started this year. It is anticipated that by 1982, all sources will be identified and quantified. During source definition, processes will be piloted and established to eliminate these sources. The final source elimination systems could be operational in 1984. Because of contamination already in the ground-water system and the slow flow rate of this system (1 to 3 feet per day), the beneficial effects at the north boundary would not be seen until at least five years after source curtailment, or 1989. Between now and 1989, contaminants would be leaving RMA at concentrations above recommended safe levels.

C. The only other course of action available is the proposed action. That is, piloting a containment and treatment system in 1978 with installation of a final system by the end of 1979. Additionally, a source elimination program is targeted to be effective by 1984. This combined approach will control the immediate off-post contaminant migration problem and provide for source elimination so that the containment system can eventually be removed. Selection of the components for the pilot system discussed in this document was based upon an evaluation of the feasible available alternatives. Consideration was given to biological treatment, membrane treatment, adsorption, and oxidation processes. The granular carbon and UV-O_3 processes have been discussed in the description of action (pages 27-29). The dewatering and recharge subsystems were chosen after a comparative study of three different proposals. The three proposals were:

1. A system composed of dewatering wells on a line near the north boundary of Rocky Mountain Arsenal to intercept the ground water; a bentonite dam further downgradient from this line of dewatering wells to assure complete interception of all contaminated flow, and recharge pits to return the water to the aquifer downgradient from the dam.

2. A French drain system composed of a barrier in the ground-water flow system to stop the flow of contaminated water, a horizontal drain (with gravel filled around a perforated pipe to collect ground water flowing into the barrier), and a similarly constructed recharge trench to return the ground water to the aquifer.

3. A hydraulic system composed of a line of dewatering wells and a recharge component. Operation of the system should result in a hydraulic gradient between the dewatering and recharge components that essentially traps the contaminated ground water.

The proposed action was chosen based upon technical data available, less technical/financial risk, proven feasibility and various operational/environmental constraints.

V. PROBABLE ADVERSE ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED

The probable environmental impact of the described actions is discussed in Section III of this EIS. The proposed action will not result in significant adverse environmental effects on the quality of the human environment.

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VI. RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

A. Short-Term Uses - A localized disruption of land use will occur due to placement of the pilot containment system. Once placement of the pilot system is complete, the major portion of the disturbed area will return to prior use, which is primarily recreation.

B. Long-Term Uses - Total effects of contaminant containment and selective source cleanup cannot be fully evaluated until after the described pilot operations are complete. Successful operation will enhance the environment by removing ground-water pollutants.

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VII. IRREVERSIBLE COMMITMENTS OF RESOURCES

A. Historical and Archaeological Disruption - No disruption of significant historical or archaeological sites is anticipated.

B. Material Consumption

1. Fuel - Approximately 15,000 gallons of diesel fuel and gasoline will be used by equipment during construction of the pilot containment system. No direct fuel expenditure will be involved in operation of the pilot containment system.

2. Electricity - Approximately 1,000,000 kilowatt hours will be used to complete the proposed action.

C. Manpower

1. The construction phase will require 5-6 man-years.

2. The operation of the pilot containment system will require 2-3 man-years per year of operation.

D. Cost

1. For construction - $366,000.

2. For operation - $200,000 per year of operation.

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VIII. OTHER INTERESTS AND CONSIDERATIONS OF FEDERAL POLICY THAT OFFSET THE ADVERSE ENVIRONMENTAL EFFECTS OF THE PROPOSED ACTION

This action will not result in any significant adverse environmental effects. Accordingly, there are no applicable interests and considerations of Federal Policy involved in this action. The only existing agreement with other Federal agencies is a cooperative plan for the protection, development and management of fish and wildlife at RMA. This agreement is between the Department of Defense, the Department of the Interior and the State of Colorado. This action does not conflict with the above mentioned plan and is being coordinated with the State of Colorado and the Department of the Interior.

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APPENDIX A

STANDARDS DEVELOPMENT

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1. General.

a. The standards development plan includes five efforts, three under the leadership of the Office of the US Army Surgeon General (OTSG) and one each under Edgewood Arsenal and Ft. Detrick. These five efforts are:

. Problem Definition

. Sampling and Analysis

. Chemistry and Toxicology Studies

. Edgewood Arsenal DIMP Toxicology Studies

. Ft. Detrick Wheat Studies (DIMP & DCPD)

b. The purpose of the first three of these efforts is to generate sound data which will be used by OTSG for recommending contamination standards to appropriate regulatory agencies. Such standards will furnish a baseline for selection of decontamination and treatment methods and determination of land use alternatives. The last two of these efforts were initiated in FY 75 to obtain preliminary data regarding the toxic effects of DIMP on mammals and vegetation (especially wheat). These efforts, prompted by damage claims by local farmers against the Government, were conducted to provide data to Army claims officers for immediate use in disposition of claims. Final reports were furnished to OTSG, who has responsibility for all future toxicology studies.

2. Problem Definition Studies.

a. Extensive literature searches are conducted to provide a data base on the physical, chemical, toxicological and biological properties of selected compounds. In addition to providing an indication of the need for additional standards development research, these studies also establish preliminary target levels to be used in the development of analytical and decontamination technology.

b. An initial problem definition study assessed 16 compounds (Table A-1) that were of known or suspected occurrence in the soil or groundwater of RMA. A second problem definition study (Table A-2) assessed 6 additional compounds. A third problem definition study (Table A-3) will be conducted on 13 compounds that have been identified in ground water through the scheduled sampling and analysis program.

TABLE A-1 COMPOUNDS ASSESSED IN INITIAL PROBLEM DEFINITION STUDY

Mustard Gas (HD)	Wheat Rust (TX)
Thiodiglycol	Arsenic Compounds
Lewisite	Mercury and mercury salts
Lewisite Oxide	Dicyclopentadiene (DCPD)
Methylphosphonic Acid (MPA)	Aldrin
Isopropyl methylphosphonate (IMP)	Dieldrin
Diisopropyl methylphosphonate (DIMP)	Endrin
Chlorate Salts	Chlordane

TABLE A-2 COMPOUNDS ASSESSED IN SECOND PROBLEM DEFINITION STUDY

Benzene	p-chlorophenyl methyl sulfide
Toluene	p-chlorophenyl methyl sulfoxide
Xylene	p-chlorophenyl methyl sulfone

TABLE A-3 COMPOUNDS TO BE ASSESSED IN THIRD PROBLEM DEFINITION STUDY

1. 1,4-dithiane
2. 1-chloro-2,3-dibromopropane (Nemagon)
3. Hexachloronorbornadiene
4. Tetrachloroethylene
5. Tetrachlorobenzene
6. Hexachlorobutadiene
7. 1,4-thioxane
8. Isodrin
9. 7-hydroxy bicyclo-[2.2.1] - hept-2,5-diene
10. Triethyl Phosphate
11. Trichloroethylene
12. Methylene Chloride/Chloroform

3. Sampling and Analysis.

The recent OTSG (1975-76) core sampling and analysis program at RMA will provide a basis for future soil sampling, chemical analyses, and toxicity studies. The pattern for this sampling program, shown in Figure A-1, was selected after evaluating water sampling data, ground-water hydrology, and historical data concerning RMA operations. During the five-month course of this program, approximately 450 soil samples were collected at selected points shown on the sampling map and forwarded to laboratories for analysis. This work was performed on contract. Cores collected during this program normally ranged in depth from 2 - 22 feet. Coring was halted prior to reaching the maximum 22 foot depth when ground water or bedrock was encountered during the operation. Deeper cores were taken if initial results indicated that they would provide additional information. Processing of the samples entailed chemical agent screening, mixing, and dividing of each sample into four parts. One of these parts was sent to Edgewood Arsenal, where it was analyzed for the presence of arsenic and mustard. Another part was analyzed at the EPA Pesticide Monitoring Laboratory for aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, cadmium, copper, zinc and mercury. The final two parts were forwarded to a contractor for phytotoxicity screening. Provisions were also made to perform a limited number of water sample analyses when the ground water was sampled during the coring operation.

4. Chemical and Toxicological Studies.

a. Chemistry Studies. Information on the intermediate products, degradation products, kinetics, photoinductive responses and synergistic effects of the compounds known to be present, and those which will be identified in the sampling and analysis program, is essential to the standards development program. Knowledge of the chemistry of the compounds and associated analytical methods is essential to synthesis of compounds dosage control for toxicity studies, and identification of metabolites. Information from the chemistry studies is supplied on a continuous basis to the contractors performing the toxicity studies.

b. Toxicity Studies. Toxicity studies are performed to provide information on those compounds identified in the problem definition studies as having insufficient data available to recommend appropriate standards to regulatory agencies. Protocols have been prepared by consultants and reviewed by the National Academy of Sciences - National Research Council

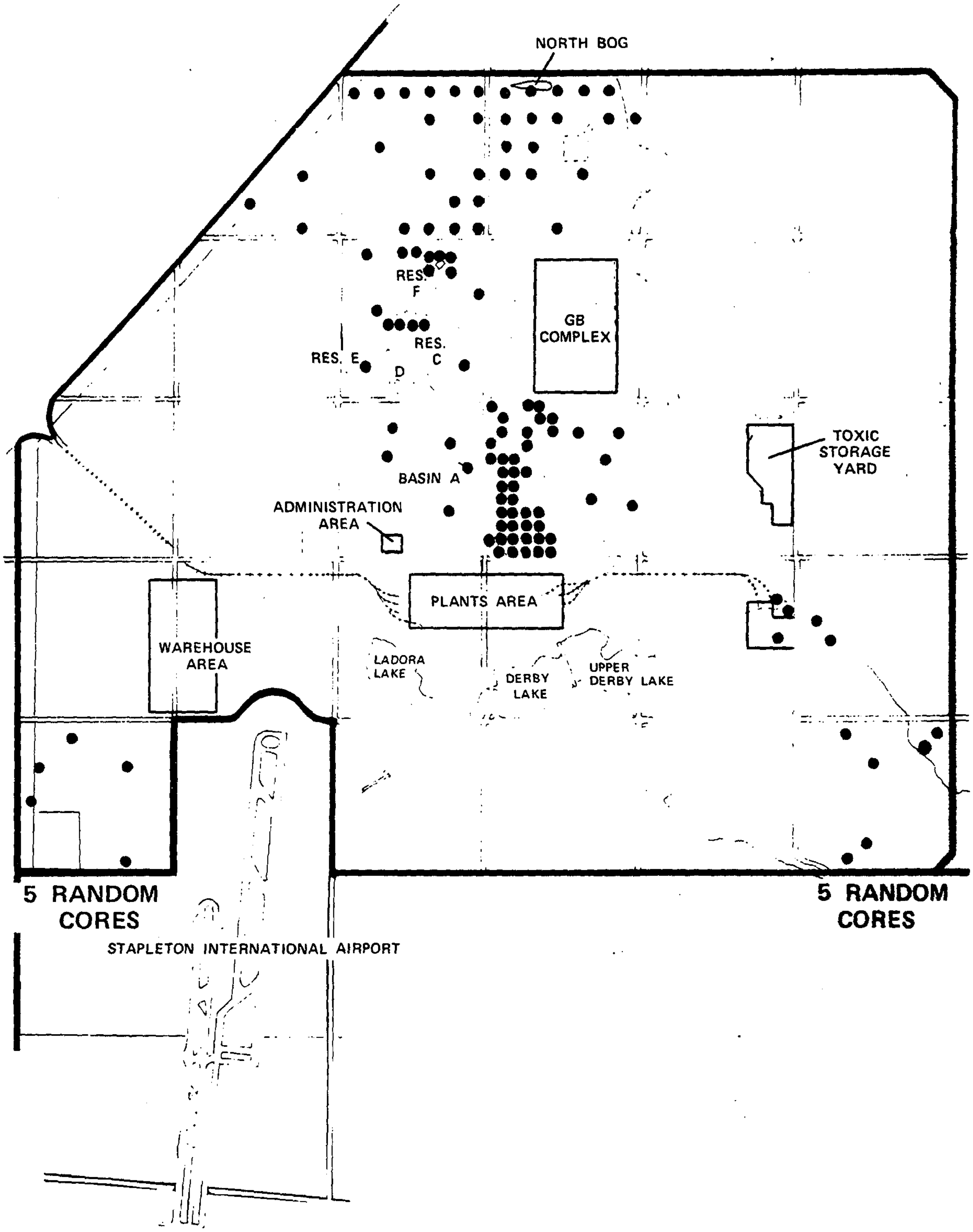

Figure A–1 OTSG CORE SAMPLING

and by Federal regulatory agencies, namely, US Environmental Protection Agency, US Department of Agriculture, US Department of Health, Education and Welfare, and US Department of Interior. This review insures that the research is both scientifically sound and consistent with the criteria established by the regulatory agencies.

Toxicity studies are being conducted in four specific areas, as follows:

(1) Mammalian Toxicity Studies. The decision to conduct mammalian toxicity studies on a contaminant has been based on both the conclusions drawn and the recommendations made in problem definition studies. Mammalian toxicity studies are being carried out in accute, subacute and chronic phases according to accepted procedures, using approved test animals. Results from acute and subacute studies determine the advisability of proceeding with chronic tests. The metabolism of the contaminant in question will be investigated, where appropriate, with emphasis on isolation and identification of metabolites. Domestic animals are included in the studies where their exposure to contaminants is shown to present a hazard to them or to humans who consume them (or who consume their milk).

(2) Aquatic Toxicity Studies. The decision to conduct aquatic toxicity work is based on the potential for a compound to migrate to off-post surface water and be a hazard to aquatic life forms. Research is conducted on representative species of the three major trophic levels in aquatic life systems (algae, invertebrates and fishes). A wide variety of test species has been examined in terms of acute toxicity. Research has also been conducted on selected aquatic species to determine the bioaccumulation potential of the contaminants, which may lead to additional adverse effects in the food chain.

(3) Wildlife Toxicity Studies. Wildlife toxicity studies are performed on subjects selected from mammalian and avian species which represent various taxa, habitats, positions in the food chain, body sizes/metabolic rates, migratory/sedentary modes of life, and sensitivities to the compounds. Acute, subacute, and chronic studies (including reproductive studies) are in progress. The standards recommended as a result of the wildlife toxicity studies will be based on the most sensitive group. Bioconcentration studies are being conducted in order to evaluate the hazard to humans consuming wildlife which may be contaminated.

(4) Vegetation Toxicity Studies. Research is conducted in the greenhouse to evaluate the potential for contaminants to cause direct injury to plant species or to cause human or animal health hazards through the food chain. These studies include initial screening of RMA soil and water samples, screening of individual contaminants, using as many as 10 different cultivated species, and detailed testing of contaminant effects. Where significant quantities of contaminants exist together at RMA, testing of compounds in combination may also be performed to assess synergistic and antagonistic effects. Detailed testing of compounds is being conducted when significant phytotoxicity and/or bio-accumulation is observed. These detailed studies involve fewer plant species, but include those species found to be most sensitive to the compound or those that are economically important to the RMA area.

5. Edgewood Arsenal DIMP Toxicity Studies.

a. In early 1975, Edgewood Arsenal was tasked, in the face of impending legal claims, to study the toxicological and reproduction effects of DIMP (Incl 1) on mammals. White rats were chosen for the study. The study continued into FY 76. The study was broken into two areas, toxicity and reproduction.

b. Summary. The results of both the toxicity study and the reproduction study showed:

(1) There was no difference between the growth rate of rats dosed with four concentrations of DIMP and those that received no DIMP (the control group).

(2) DIMP had no effect on the water consumption of the rats.

(3) There were no gross or microscopic lesions seen that were directly related to ingested DIMP.

(4) There does not appear to be any effect upon the reproduction cycle of the rats when exposed to 10 ppm or 1,000 ppm DIMP in the drinking water.

6. Ft. Detrick Wheat Studies, DIMP, and DCPD

These studies at Ft. Detrick started in Sep 74 and continued into FY 76 to determine the effect of 0.5, 2,5, 5.0, and 10.0 parts per million aqueous solutions of DIMP on the development of wheat from germination to maturity. Ordinary tap water was used for the control wheat. Data collected was

limited to external, visual observation of the plants. Further study was initiated in Dec 74 by Ft. Detrick to determine the effect of 10.0 and 40.0 ppm aqueous solutions in both DIMP and DCPD. Again, tap water was used for the control wheat. A final report, furnished the OTSG, stated that levels in excess of 10 ppm produces some tip burn of plant leaves.

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INCLOSURE 1

DIISOPROPYL METHYLPHOSPHONATE

ALTERNATIVE NAMES

Diisopropyl methylphosphonate; DIMP; phosphonic acid, methyl-, bis-(1-methylethyl) ester (Chem. Abstr. after 1971); phosphonic acid, methyl-, diispropyl ester (1947-1971); methanephosphonic acid, diisopropyl ester.

PHYSICAL AND CHEMICAL PROPERTIES

CAS Reg. No. 1445-75-6
Toxic Substances List: Not listed
Edgewood Arsenal Number: EA 1250
Wiswesser Line Notation: 1Y&OPO&1&OY
Molecular formula: $C_7H_{17}O_3P$

Structural formula: $((CH_3)_2CHO)_2(CH_3)P=O$

DIMP is a liquid at room temperature with $n_D^{20}=1.4112$ (1), a bulk density at 25°C of 0.976 g/cc and a boiling point of 174°C (2, 3). Its vapor pressure-temperature behavior is closely approximated by the following empirical relationship (2, 3).

$$\text{Log } P(\text{mm of Hg}) = 9.8571 - 3105/T(^\circ K)$$

DIMP is best synthesized through the reaction of methyl iodide with triisopropyl phosphite (4, 5). Other methods are mentioned in the patent literature (6, 7, 8).

Very little is known of DIMP solubility in water. In studies of DIMP hydrolysis in acidic and basic solutions (9), 0.12 N or higher DIMP was used at temperatures above 80°C, indicating solubilities of above 11 g/liter in that temperature range. In DIMP studies at Southeast Research Institute (10), the solubility in water at 25°C was between 1 and 2 g/liter.

DIMP hydrolysis rates in water at 98, 90 and 80°C have been reported as 2×10^{-6}, 0.88×10^{-6} and 0.31×10^{-6} sec^{-1} respectively (11). The hydrolysis activation energy was estimated to be 26.9 Kcal/mole. These reaction rates can be used to predict hydrolytic behavior at 10°C, a temperature more representative of ground water in a temperate climate. The estimated rate is 3.2×10^{-11} sec^{-1}, corresponding to a hydrolysis half-life of about 687 years. In studies cited previously

(9), DIMP was among a series of alkylphosphonate esters whose hydrolysis characteristics were measured. In 1N HCl solution, rate constants of 1.74×10^{-4}, 2.81×10^{-4}, 4.78×10^{-4}, 8.53×10^{-4} and 8.56×10^{-4} sec^{-1} were determined at 88.9, 94.4, 99.7, 104.8 and 105.9°C, respectively (9). The acid hydrolysis appears to proceed by the S_N1 mechanism, since the rate of DIMP hydrolysis is greater than that of the lower alkyl phosphonate esters. Basic hydrolysis appears to proceed by the S_N2 mechanism, since the DIMP hydrolysis rate is less than that of the lower alkylphosphonate esters. Typical rate constants for 0.12 N DIMP in 0.2N NaOH solution were 1.53×10^{-4}, 2.29×10^{-4}, and 4.82×10^{-4} $M\ sec^{-1}$ at 80, 90 and 100°C respectively. Basic hydrolysis at elevated temperatures is a convenient way to prepare the monoester, isopropyl methylphosphonate. In DIMP studies at Southeast Research Institute (10), the mono-sodium salt of DIMP was prepared by dissolving DIMP in 2N NaOH, heating to 50°C, followed by slow cooling to room temperature, with stirring applied throughout the process. About four days were required for completion of the hydrolysis reaction. It would appear that at room temperature and mildly basic conditions, hydrolysis of DIMP would be quite slow. DIMP is formed from sodium isopropyl methylphosphonate at 270°, but DIMP is also converted, in part, to trimethylphosphine oxide at this temperature (12). DIMP is decomposed almost entirely on short residence in a microwave plasma discharge (13); among the products are methylphosphonic acid, isopropyl methylphosphonate, phosphoric acid, isopropyl alcohol, and propylene.

DIMP forms a number of metal complexes in the absence of moisture (14, 15, 16).

DIMP does not appear to be a cholinesterase inhibitor (17).

ANALYTICAL METHODS

DIMP analysis by infrared and Raman spectra was reported by Meyrick and Thompson in 1950 (18). Strong infrared bands occur at 504, 983, 1008, 1248 (phosphonyl), and 2983 cm^{-1}, while strong Raman bands occur at 710, 1445, 2930 and 2985 cm^{-1}. Christol, Levy and Marty listed infrared absorptions at 987, 1015 and 1244 (phosphonyl) cm^{-1}. Moores (19) reported absorptions at 899, 1239 and 1314 cm^{-1}. The spectrum of DIMP was also studied by Lorquet and Vassart (20). Unfortunately, other alkylphosphonate esters have similar absorption bands.

Thin-layer and paper chromatography methods for DIMP have been studied (21). A 2:1:1 v/v solution of hexane-benzene-methanol or a 6:1:1 v/v solution of hexane-methanol-diethyl ether was used to develop the paper chromatogram. Spots were made visible with a spray of 1% cobalt chloride in anhydrous acetone, which detected DIMP and other phosphorous esters. These esters appeared at room temperature as blue spots, which could be distinguished by their relative R_f values. DIMP detection levels were not given.

Gas chromatography has been used to analyze DIMP in water with a flame ionization detector. Two methods are known; one developed by Shell Chemical Company (22) and adopted by the Colorado Department of Health (23) and one developed at Edgewood Arsenal (12). The Colorado Department of Health methodology (23) involves extraction of DIMP from water with chloroform. Three ml of chloroform suffices to extract 85-90% of DIMP from 200 ml of water. The glass chromatographic column was 5 ft long, ¼ inch in diameter, and filled with OV-17/Reoplex on 400 CRG. A 1 ppm solution of DIMP in chloroform was used as a standard.

The Edgewood Arsenal work (12) was oriented towards determining components of waste from demilitarized methyl isopropylphosphonofluoridate (GB). The waste is extracted with methylene chloride. The chromatography column was of glass, 6 ft long x ¼ inch in diameter and filled with QF-1 in 60-80 mesh Gas Chrom Q. GB could be detected by phosphorus flame photomety as 20 ppb (12); no limits were mentioned for DIMP or other compounds. Field ionization mass spectrometry (24) can be used to detect as little as 0.2 ppb (mole ratio), i.e., 10^{-9} g/liter.

The nuclear magnetic resonance spectrum of DIMP at 25 MHz was studied by Mavel and Martin (25).

MAMMALIAN TOXICOLOGY

No published information is available on the toxicity of DIMP to humans or experimental animals. Unpublished acute toxicity data (LD50) on experimental animals were obtained from the files at Edgewood Arsenal, and are summarized in Table E-1.

TABLE E-1

Summary of Acute Toxicity of DIMP

Animal Species	Route of Administration	LD50 (mg/kg)	Remarks	References
Mouse	Intraperitoneal	>250		26
Rat	Subcutaneous	>200		27
Rabbit	Subcutaneous	>100 <200		27
"	Intravenous	224	Local irritation 179-280 (19/20 confidence limits)	28
"	Dermal	>200	No irritation at application site	28

The toxicology of DIMP, including acute data, phytotoxicity and detoxification studies have been summarized in a fact sheet (2). No evidence was found that DIMP has been studied for carcinogenic, mutagenic or teratogenic activity in vitro. One report (17) stated that DIMP does not inhibit the enzyme cholinesterase, although no experimental evidence was given for the statement.

It is concluded from the data presented above, that DIMP is fairly toxic to experimental animals and could be irritating or corrosive to the eyes. The lack of complete data indicates the need for further studies to accurately evaluate the potential toxicity of DIMP. Recommendations for further toxicological studies were made (2) and these have been implemented through a USAMRDC contract with Litton Bionetics Inc., Falls Church, Virginia 22046.

An additional study on DIMP has been initiated (May 1975) in the Toxicology Division, Biomedical Laboratory, Edgewood Arsenal, APG, MD (29). This work includes a 26 week subacute study and a reproduction study in rats only.

ENVIRONMENTAL CONSIDERATIONS

No information was found as to DIMP behavior in soil and water, its effect on animals in the environment, or its transmittal in food chains. A USAMRDC contract study to determine the toxicity of DIMP to aquatic vertebrates and invertebrates has been initiated through Bionomics, E. G. & G., Inc., Wareham, MA 02571.

Plants

Evaluation of DIMP at Ft. Detrick during 1974-1975 indicated that DIMP could injure wheat and beans (Witchita wheat and Black Valentine beans) (30). In one test, treatment of wheat and beans (water solution to soil) with 10 ppm DIMP produced no effect on wheat, but gave a burning on edges of bean leaves. In a second test, treatment with 10 ppm or 40 ppm levels of DIMP resulted in tip burn of leaves on both wheat and beans at both levels. In other tests where DIMP and dicyclopentadiene (DCPD) were used together, there was an indication of additive or synergistic effects due to DCPD. DIMP may also be phytotoxic to sugar beets (31). In herbicidal screening tests at Ft. Detrick, rice, morning glory, bean, oat and soybean plants growing in pots in a greenhouse and sprayed with DIMP at 0.1 and 1.0 pounds per acre exhibited no injurious effects from the DIMP (32). A USAMRDC contract study to determine plant uptake and effects and soil retention of DIMP has been initiated through Aerojet Ordinance and Manufacturing Co., Downey, CA 90241.

EXISTING STANDARDS

No information available.

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DICYCLOPENTADIENE

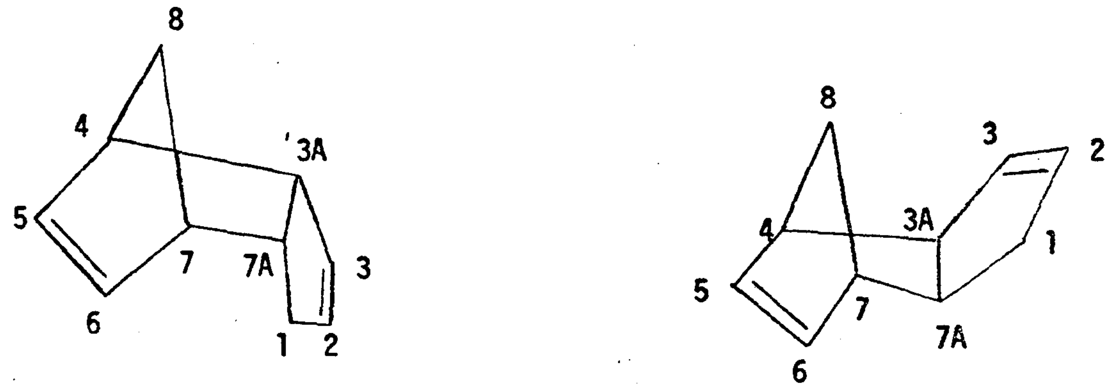
ALTERNATIVE NAMES

Dicyclopentadiene; Bicyclopentadiene; Biscyclopentadiene;
3a,4,7,7a-Tetrahydro-4,7-methanoindene

PHYSICAL AND CHEMICAL PROPERTIES

CAS Reg. No. 0077-73-6
Toxic Substances List: PC 10500
Molecular formula: $C_{10}H_{12}$

Dicyclopentadiene (DCPD) is a waxy solid at room temperature with a strong camphor-like odor. The structures of DCPD appear in Figure J-1. The isomers may be considered as cis- and trans- in terms of the 2- and 8-carbons. Trans-DCPD is the usual form, (and where DCPD is cited the trans-form is understood). The cis- form has been prepared from the trans-form by a method described by Schröder (1). A 20% solution of DCPD in CS_2 was heated for 2 to 4 hours at 180°-200°C under 50 atmospheres pressure. The solvent was then distilled, and the products separated by *in vacuo* distillation with a 30% yield of cis-DCPD.



"Trans" "Cis"

Figure J-1. Cis- and Trans- Isomers of Dicyclopentadiene

According to an article by Waring and co-workers (2), crude DCPD was distilled, and 40°-44°C range distillate (probably monomer) collected and allowed to stand overnight. The cis- isomer reportedly crystallized when the distillate was placed in vacuum, had a melting point of 27.8°C, and only a faint odor.

Table J-1 summarizes physical properties of trans-DCPD.

TABLE J-1

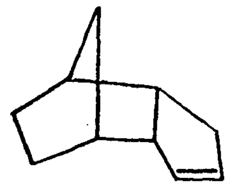
Physical properties of Trans-Dicyclopentadiene

Property	Value	References
Density at 20°C, g/cc	0.982	(3)
Melting Point, °C	32.9	(4)
n_D^{35} (Refractive Index)	1.5050	(5)
Temp, °C for cited Vapor Press, mm Hg		
20°	1.4	(3)
47.6°	10	(6)
105°	100	(3)
166.6° (boiling point)	760	(4)
Solubility in Water (ppm)	Considered insoluble Estimated 40*	(6) (6a)

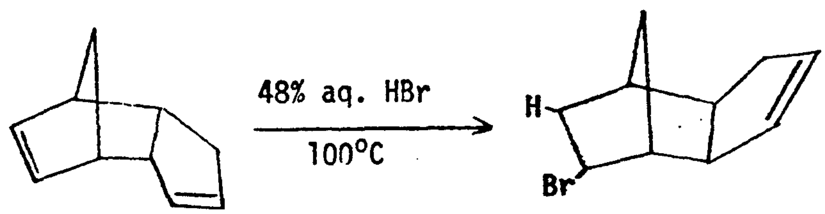
*Estimation on basis of solubility of diolefins of similar molecular volume (6a).

Dicyclopentadiene can be prepared by dimerizing cyclopentadiene. Harkness *et al.* (7) reported that the second-order rate constant for the reaction in liquid cyclopentadiene was $8.5 \times 10^7 e^{-14900/RT}$ cc/mole-sec. Thus, if one cc of cyclopentadiene is allowed to stand at 25°C for one day, 52% conversion to the dimer should occur. This result is approximate since the liquid phase changes density as dimerization proceeds. DCPD in turn can break down to the monomer. These authors (7) determined the breakdown to be a first-order reaction in the vapor phase with rate constant $10^{13} e^{-33,700/RT}$ sec^{-1}. In 1936, Khambata and Wassermann (8) reported the liquid phase rate constant as $3 \times 10^{13} e^{-35400/RT}$ sec^{-1}. At 30°C, the half-lives of DCPD breakdown in the vapor and liquid phases are calculated at 4,315 and 24,200 years, respectively. This means that the equilbrium between the monomer and dimer of cyclopentadiene lies strongly on the side of the dimer at ambient temperatures. The 584Å photoelectron spectrum of DCPD was measured by Baker *et al.* (9). DCPD undergoes reactions involving its double bonds; some of these were studied in a thesis by Donaldson in 1958 (10). If addition is made across one

double bond, it is inevitably the 5,6-bond. DCPD can be hydrogenated in the presence of Raney nickel to



However, typical addition reactions such as hydrohalogenation, hydration or esterification yield rearranged structures which are cis-oriented. For example:



Donaldson (10) found that 99% of the saturated analogue of DCPD, trans-4,7-methanoindan, could be isomerized to the cis-4,7-methanoindan, in sharp contrast to DCPD. He presented the infrared spectrum of DCPD (identified as Spectrum #46) and spectra of the other compounds studied. Although he did not investigate the reaction of HOCl with DCPD, he indicated that addition occurs across the 5,6-bond to form a chlorohydrin (10).

ANALYTICAL METHODS

Until recently, analysis for DCPD as a trace pollutant was not well developed. According to a 1967 article by Szewczyk (11), DCPD absorbs in the infrared at 677 and 1344 cm^{-1} sufficiently distinct from the cyclopentadiene peaks of 644 and 1369 cm^{-1} to permit analysis of DCPD in the presence of cyclopentadiene. Raman spectrum frequencies are found at 1571 and 1613 cm^{-1} (12). Miskalis (13) used gas chromatography to detect DCPD in coke-oven gas. Gas chromatography of mixtures containing DCPD was reported as early as 1958 (14). Kinkead, *et al.* (3) used flame ionization gas chromatographic analysis (at 135°C, with a 10 ft column of 15% Tergitol NP-44 on Gas Chrom Q) to measure DCPD concentrations as low as 1 ppm in air. In work done for the Colorado State Department of Health, headspace analysis by gas chromatography was performed on water containing DCPD (15). Details of the analysis are not available, though it is claimed to detect DCPD at 0.28 ppb in water (16). DCPD in a benzene-acetic acid mixture gives a color text with bromine at a sensitivity of about 60 ppm (17). DCPD exhibits a fluorescence that might be useful for analysis (18).

DCPD was found to be an irritant when subjected to the standard rabbit eye irritation test but was not found to be a primary skin irritant (20). No TLV has been established for DCPD, but Gerarde (6) suggested "a value of 100 ppm seems reasonable based on the limited toxicity data available and extrapolation from similar chemicals." Kinkead *et al.* (3) have suggested a hygienic standard for man of 5 ppm. The TLV for DCPD recommended by Russian workers (24, 25), is 0.185 ppm (1 mg/m^3). Russian workers (26) have also recommended a permissible concentration of 0.0001 mg/l for DCPD in water supply systems. Man can detect 0.003 ppm DCPD vapor by odor (3).

The carcinogenicity of DCPD by intramuscular injection in the rat was investigated under an NCI contract at the Institute of Chemical Biology, San Francisco University (Dr. A. Furst, 1975) (27). The compound was not considered to be carcinogenic under the conditions of the experiment.

The toxicology of DCPD, including phytotoxicity, has been summarized in a fact sheet (28). The pathological effects in rats were typical of irritating hydrocarbons when administered orally in large doses; it is slightly to moderately toxic by the dermal route; and highly toxic by the oral and intraperitoneal routes in single dose studies. The lack of complete data indicates the need for further studies for an accurate evaluation of the toxic potential of DCPD. Recommendations for further toxicological studies have been made (28), and the implementation of these recommendations has already been undertaken through a USAMRDC contract with Litton Bionetics Inc., Falls Church, Virginia 22046.

ENVIRONMENTAL CONSIDERATIONS

No information is available as to DCPD behavior in soil and water, its effects on animals in the environment, or its transmission through food chains. A USAMRDC contract study to determine the toxicity of DCPD to aquatic vertebrates and invertebrates has been initiated through Bionomics, E. G. & G., Inc., Wareham, MA 02571.

Plants

Tests conducted at Ft. Detrick during 1974-1975, in which wheat (Wichita) and beans (Black Valentine) were treated with diisopropyl methylphosphonate (DIMP) and DCPD combined (water solution to soil), showed a greater effect on test plants than treatments with DIMP alone. Thus an additive, or possible synergistic, effect due to DCPD was suggested. Tests conducted with DCPD alone at 10 and 40 ppm caused tip burning of leaves (29). A USAMRDC contract study to determine plant uptake and effects and soil retention of DCPD has been initiated through Aerojet Ordnance and Manufacturing Co., Downey, CA 90241.

EXISTING STANDARDS

No information available.

MAMMALIAN TOXICOLOGY

There is no published information on the toxicity of DCPD to humans. Information on the mammalian toxicity of DCPD is summarized in Tables J-2 and J-3.

TABLE J-2

Summary of Acute Toxicity of DCPD

Animal Species	Route of Administration	LD50 (mg/kg)	Range Value	References
Rat	Oral	353	262-478	3
		410	310-530	19
Rat (male)	"	435	361-523	20
Rat (female)	"	396	343-458	20
Rat	Intraperitoneal	200		21
		310		3
Mouse	"	200		21
Rabbit	Dermal	5080*	3110-8290	3
		4460*	2440-8150	19
		6720*	3150-14360	22

* LC50 values.

TABLE J-3

Inhalation Toxicity of DCPD

Animal Species	Dose (ppm) & Exposure (hr)	LC50 (ppm)	Remarks	References
Rat	4	660	Range 553-817	3
"		359		3
"		385		3
"	Saturated vapor	1*		3
Mouse (male)	4	145		3
Rabbit (male)	4	771		3
Rat	2500/1		1/4 killed	23
"	2000/4		4/6 "	23
"	1000/4		4/4 "	23
"	500/4		1/6 "	23
"	250/6 x 10		1/4 "	23
"	100/6 x 15		4/4 "	23

* LT 50 (hr.)

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APPENDIX B

CEASE AND DESIST ORDERS

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STATE OF COLORADO, DEPARTMENT OF HEALTH

DIVISION OF ADMINISTRATION

IN THE MATTER OF UNAUTHORIZED DISCHARGE OF POLLUTANTS BY SHELL CHEMICAL, INC., and/or UNITED STATES ARMY, ROCKY MOUNTAIN ARSENAL

DOCKET NO. 75 LS 012

FINDINGS OF FACT AND ORDER

25-8-605, C.R.S. 1973

FINDINGS OF FACT

Pursuant to the above-referenced statutory authority, I hereby make the following findings of fact:

1. Based upon information obtained by authorized representatives of the State of Colorado Department of Health (hereinafter referred to as Department), the Shell Chemical Company (hereinafter referred to as Company) and/or the United States Army, Rocky Mountain Arsenal (hereinafter referred to as Arsenal) is/are in violation of 25-8-501, C.R.S. 1973. The aforesaid statutory section prohibits the discharge of any pollutant into any state water from a point source without first having applied for not after December 31, 1974 without having obtained a permit from the division for such discharge.

2. No application for a permit exists nor has a permit been issued to either the Company or the Arsenal for the open ditch which runs northernly from the arsenal property. (This is the ditch which crosses under 96th Avenue approximately 1/2 mile east of Peoria Street.) Such ditch constitutes a point source within the meaning of 25-8-103(10) and 25-8-501(1), C.R.S. 1973.

3. That on May 13, 14, 20, 22 and 23, 1974, representatives of the Department sampled the discharge in the aforesaid ditch and identified the presence of the chemical substance known as dicyclopentadiene occurring in the aforesaid ditch on all occasions. The chemical substance known as diisopropylmethylphosphonate was identified in the samples taken on May 13, 22, and 23, 1974. The discharge was first observed and identified on or about May 13, 1974, and has continued to the present time. The above-mention substances constitute pollutants within the meaning of 25-8-103(11), C.R.S. 1973.

ORDER

Based upon the foregoing findings of fact and pursuant to the provisions of 25-8-605, C.R.S. 1973, I hereby order:

1. That the Company and/or Arsenal take such steps as are necessary to cease and desist from all unauthorized discharges to the waters of the State of Colorado via the unnamed ditch.

2. That the Company and/or Arsenal perform any work necessary to prevent future unauthorized discharges through the aforesaid point source.

3. That the Company and/or Arsenal file with the Department a properly prepared application for discharge permit for the aforesaid unnamed ditch within ten (10) days of their receipt of this order.

4. That within 10 (10) days of their receipt of this order, the Company and/or Arsenal submit to the Department a proposed schedule of compliance with paragraph 1 of this cease and desist order.

5. That within thirty (30) days of their receipt of this order, the Company and/or Arsenal submit to the Department a proposed schedule of compliance designed to meet the requirements in paragraph 2 of this order.

DATES this ___7th___ day of April, 1975.

COLORADO DEPARTMENT OF HEALTH
Division of Administration

SIGNED

Edward G. Dreyfus, M.D., M.P.H
Executive Director

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STATE OF COLORADO, DEPARTMENT OF HEALTH

DIVISION OF ADMINISTRATION

IN THE MATTER OF UNAUTHORIZED DISCHARGE OF POLLUTANTS BY SHELL CHEMICAL, INC., and/or UNITED STATES ARMY, ROCKY MOUNTAIN ARSENAL

Docket No. 75 LS 012

FINDINGS OF FACT AND ORDER

25-8-606, C.R.S. 1973

FINDINGS OF FACT

Pursuant to the above-referenced statutory authority, I hereby make the following findings of fact:

1. Based upon information obtained by authorized representatives of the State of Colorado Department of Health (hereinafter referred to as Department), the Shell Chemical Company (hereinafter referred to as Company) and/or the United States Army, Rocky Mountain Arsenal (herein referred to as Arsenal) have accidently or purposely dumped, spilled or otherwise deposited in or near state waters, material which may pollute or has polluted said waters, to wit, the ground waters on and near the Arsenal.

2. Based on information obtained by authorized representatives of the Department, the chemical substances diisoproplymethylphosphonate (hereinafter DIMP) and dicyclopentadiene (hereinafter DCPD) have been identified in the ground water aquifer located under and to the north of the site of the facilities of said Company and Arsenal.

3. The presence of such substances constitutes pollution of the waters of the State within the meaning of section 25-8-606, C.R.S. 1973.

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ORDER

Based upon the foregoing findings of fact, pursuant to the provisions of section 25-8-606, C.R.S. 1973, I hereby order:

1. That the Company and/or Arsenal immediately take whatever steps are necessary to clean up all sources of the substances DIMP and DCPD located at their facilities northeast of the City of Denver, known as the Rocky Mountain Arsenal.

2. That the Company and/or Arsenal perform all work necessary to insure that existing sources of the substances DIMP and DCPD cannot enter the water of the State to include the ground water from the date of this order onward.

3. That within ten (10) days of their receipt of this order, the Company/or Arsenal give written notice to the Department of their compliance with paragraph 1 of this order.

4. That within thirty (30) days of their receipt of this order, the Company and/or Arsenal have completed a proposed plan to meet the requirements of paragraph 2 of this order to the satisfaction of the Department.

DATED this 7th day of April, 1975.

COLORADO DEPARTMENT OF HEALTH
Division of Administration

SIGNED

Edward G. Dreyfus, M.D., M.P.H.
Executive Director

STATE OF COLORADO, DEPARTMENT OF HEALTH

DIVISION OF ADMINISTRATION

IN THE MATTER OF UNAUTHORIZED DISCHARGE OF POLLUTANTS BY SHELL CHEMICAL, INC. and/or UNITED STATES ARMY, ROCKY MOUNTAIN ARSENAL

Docket No. 75 LS 012

FINDINGS OF FACT AND ORDER

25-8-304, C.R.S. 1973

FINDINGS OF FACT

Pursuant to the above-referenced statutory authority, I hereby make the following findings of fact:

1. Based upon information obtained by authorized representatives of the State of Colorado Department of Health (hereinafter referred to as Department), the Shell Chemical Company (hereinafter referred to as Company) and the United States Army, Rocky Mountain Arsenal (hereinafter referred to as Arsenal) operate a facility, process, or activity from which there is a discharge of pollutants into state waters as defined in section 25-8-103(16), C.R.S. 1973.

2. Pursuant to the above-referenced statutory authority, the owner-operator of a facility from which such a discharge of pollutants is made may be required to establish and maintain records, make reports, install, calibrate, use and maintain monitoring methods and equipment, and sample discharges.

ORDER

Based upon the foregoing findings of fact and pursuant to the provisions of section 25-8-304, C.R.S. 1973, I hereby order:

1. That the Company and/or Arsenal initiate and continue a program of ground water surveillance to determine the geographical extent of diisopropylmethylphosphonate and dicyclopentadiene pollution. Said program is to be established and pursued under the supervision of the Department.

2. That the program thus established include, as a minimum, the monitoring of wells designated by the Department at a frequency no less than two times per week.

3. That the Company and/or Arsenal report the results of the by-weekly monitoring to the Department no later than the Friday following the week monitored.

4. That the Company and/or Arsenal establish and maintain a complete set of records of the results of all monitoring and sampling activity carried out on the arsenal grounds and in the surrounding area.

5. That the monitoring program be commenced no later than twenty (20) days from the date of receipt of this order.

DATED this 7th day of April, 1975.

COLORADO DEPARTMENT OF HEALTH
Division of Administration

SIGNED

Edward G. Dreyfus, M.D., M.P.H.

Executive Director

APPENDIX C

PRELIMINARY ECOLOGICAL WORK

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1. Vegetation - A preliminary vegetation survey of RMA was conducted in the summer and fall on 1975. This survey involved the use of systematically spaced plots and many spot checks, as well as black and white aerial photographs. As a result, ten major vegetation cover types were identified and mapped (see Figure B1). Table B1 lists the approximate area on RMA covered by each vegetation type and a brief description of each vegetation type is provided below.

a. Early Successional - The early successional or weedy vegetation types represent areas which have been recently disturbed. The dominant species in these types are primarily annual forbs and grasses. Some of the most abundant species are cheatgrass, prickley lettuce, tumble-mustard, tansy-mustard, kochia, Russian thistle, morning-glory, western ragweed, ground-cherry, prairie sunflower, whitchgrass, and horseweed.

b. Crested Wheatgrass - This vegetation type is dominated by crested wheatgrass, an Asiatic species planted for soil stabilization. This species often forms almost a pure stand. However, in many areas, red threeawn, sand dropseed, or cheatgrass are present as co-dominants. Common forbs include hairy golden-aster and western ragweed.

c. Sand Dropseed - This type represents a successional stage midway between the early successional and climax stages. It is dominated by sand dropseed with either cheatgrass or red threeawn as co-dominants. Prickley-lettuce or morning-glory are often also abundant in association with cheatgrass. Other representative forbs include croton, Russian thistle, western ragweed, and slender-flowered scurf-pea.

d. Needle and Thread - The needle-and-thread vegetation type is found chiefly on the sandier soils and ridges of RMA. It is dominated by needle-and-thread either alone or in combination with sand stagebrush and sometimes prairie sandreed. Many annual and perennial forbs are generally present.

e. Western Wheatgrass - Western wheatgrass is a dominant species in small areas on RMA. It often forms a uniform sod, excluding most other species. However, in some areas, a variety of other plants is associated with it.

f. Red Threeawn - This vegetation type represents a late stage in succession. Red threeawn is generally dominant, although hairy golden-aster, cheatgrass, or sand dropseed may also be abundant. Copper mallow, prairie sunflower, common rabbitbrush, and broom snakeweed are locally common. The red threeawn vegetation type frequently occurs in prairie dog towns due to the low palatibility of the dominant species.

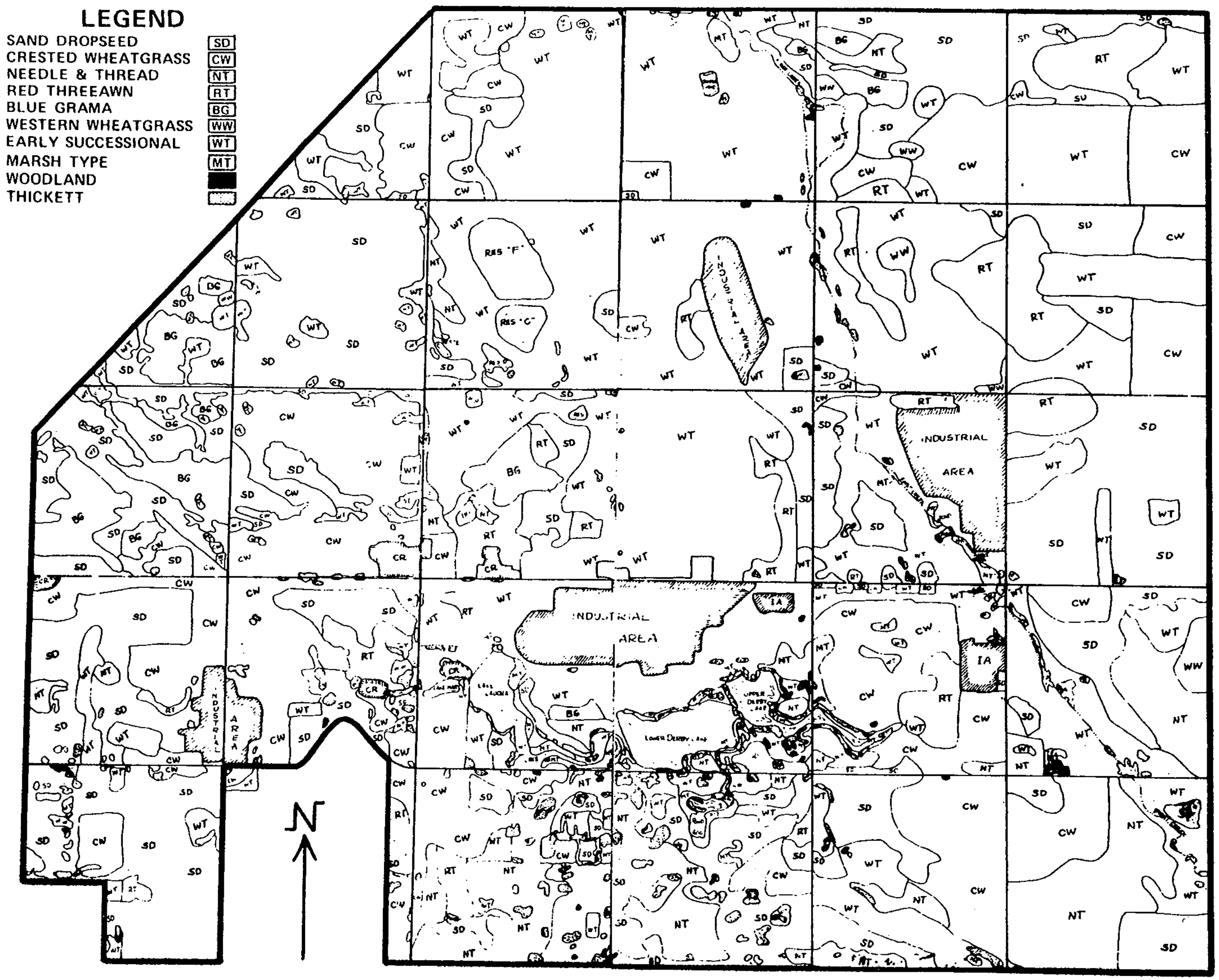

FIGURE C-1
GENERAL VEGETATION MAP, RMA

TABLE C1. APPROXIMATE AREAS OCCUPIED BY THE MAJOR VEGETATION COVER TYPES ON RMA

Vegetation Types	Area (Acres)	Percentage of RMA
Early Successional	5,515	32.5
Crested Wheatgrass	2,880	17.0
Sand Dropseed	4,360	25.7
Needle-and-Thread	995	5.9
Western Wheatgrass	100	0.6
Red Threeawn	835	4.9
Blue Grama	500	3.0
Marsh Type	185	1.1
Woodland	320	1.9
Thicket	125	0.7
Other Categories		
Lakes and Ponds	360	2.1
Commercial and Residential Areas	65	0.3
Industrial Areas	735	4.3
TOTAL	16,975	100.0

g. Blue Grama - The blue grama vegetation type represents the climax shortgrass prairie stage of succession. Blue grama is the dominant species, often forming a dense sod, with such mid grasses as squirreltail, sand dropseed, or red threeawn as co-dominants. Common forbs include copper-mallow, Fendler's cryptantha, prairie sunflower, sand lily, and Russian thistle.

h. Marsh Type - Several vegetation cover types are included within the marsh type category. These are located in patches along First Creek, some of the canals, the lakes and ponds, and other low-lying moist areas. Narrow-leaved cattail is the dominant plant in shallow water or very wet areas. Smartweed, sedges, and American bullrush are locally common in these areas. On moist areas where the ground surface is above the water table, alkali salt-grass, rabbitsfoot grass, or squirreltail often form a dense cover.

i. Woodland - The woodland cover type consists of plantings around old farmsteads, along roads, wind-breaks, and riparian plains cottonwood, with an understory often dominated by willows. The other woodlands consist of a variety of trees with Chinese elm, plains cottonwood, white poplar, Rocky Mountain juniper, ponderosa pine, and boxelder as the most abundant. Lilacs, snowberry, and other planted shrubs frequently form a shrub-lever in the understory.

j. Thicket - Thicket cover types consist of almost pure stands of either black locusts or willows. Black locust thickets are by far the most common. The locusts form a dense, almost impenetrable stand, from 5 to 20 feet tall, with a low diversity of forbs or grasses. These thickets have developed from black locusts planted by the original land owners. The willow thickets are also dense in character and are found in scattered locations along the water courses of RMA.

2. Invertebrates - Although only limited studies have been made to date on the invertebrates of RMA, it is known that a great diversity of species exist. A few of the important invertebrates will be discussed here:

a. The grasshoppers (orthoptera) probably constitute the most important group of invertebrates present on RMA. These insects are abundant throughout the summer period and occasionally become so dense that they do considerable damage to the natural vegetation and wildlife food crops. In contrast to their potential destructiveness, however, grasshoppers provide a major food source for many of the birds and mammals occupying the arsenal.

b. Harvester ants (pogonomyrmex) are also conspicuous inhabitants of the prairie of RMA. They denude the vegetation in circles from a few to 20 feet or more in diameter around their mounds. They collect and store very large quantities of seeds and are used as food items by many amphibians, reptiles, birds, and mammals, as well as other insects.

c. Beetles (coleopera), moths and butterflies (lepidoptera), bees and wasps (hymenoptera), and many of the lower invertebrates are abundant and highly important organisms in the natural environment of RMA. They are extremely important in the decomposition of organic matter, as food sources for other animals, for the pollination of many plants, for aeration of the soil, and for many other reasons.

3. Fish - Fish inhabit all of the permanent water bodies on RMA. Eleven species have been identified to date (see Inclosure 1). Most of these have been stocked or have been introduced via their irrigation canals.

a. At present, black bullheads, northern bluegills, large-mouth bass, western white suckers, and green sunfish are the most abundant species in the three large reservoirs (Lake Ladora, Lower Derby, and Upper Derby). Black bullhead populations are largest and growing rapidly. Recently, a large number of northern pike fingerlings were stocked.

b. Lake Mary, which was recently deepened and widened, contains fishable populations of rainbow trout and channel catfish. It is the only lake on the arsenal where fish may be caught and retained.

4. Amphibians and Reptiles - RMA supports a variety of amphibians and reptiles. A total of 12 species have been identified to date on the arsenal, out of 20 species which have been recorded from Adams County.

a. The bullsnake is probably the most abundant reptile throughout RMA, while the lesser earless lizard is common in exposed sandy areas; and the plains garter snake is common in marshy or moist habitats. The prairie rattlesnake is relatively uncommon.

b. The permanent lakes of RMA support large populations of bullfrogs. Other common amphibians include the plains spacefoot and tiger salamander.

5. Birds - RMA supports a great diversity of bird life, primarily due to the variety of habitats present. To date, over 180 species have been observed and identified within the arsenal boundaries. This number includes approximately 43 permanent residents, 47 summer residents, and 26 winter residents.

a. The most abundant breeding birds of the prairie habitats of RMA include the western meadowlark, lark bunting, horned lark, mourning dove, brewer's sparrow, and ring-necked pheasant. The lark bunting and horned lark are primarily restricted to shortgrass vegetation, such as the blue grama and red threeawn vegetation cover types, and the brewer's sparrow is common only in areas with scattered shrubs. During winter, the western meadowlark, horned lark, common redpoll, lapland longspur, and ring-necked pheasant are among the dominant prairie species.

b. The scattered trees, thickets, and woodlands of RMA provide nesting habitat for black-billed magpies, eastern and western kingbirds, house wrens, starlings, northern orioles, common grackles, and many others. The tree sparrow, white-crowned sparrow, dark-eyed junco, starling and black-billed magpie are common wintering birds of the woodland habitat.

c. The lakes, ponds, and marshes of RMA support many species of aquatic and marsh birds. Common breeding birds include several species of waterfowl, red-winged, and yellow-headed blackbirds, and common yellowthroats. Many species of waterfowl, including large numbers of Canada geese, as well as other birds, utilize these habitats during the winter.

d. In addition to supporting the typical breeding birds of eastern Colorado, RMA supports breeding populations of several species which breed only locally or rarely on the eastern plains. The short-eared owl, tree swallow, mockingbird, sage thrasher, orchard oriole, grasshopper sparrow, and brewer's sparrow, as well as other species, are in this category.

e. Another unique characteristic of RMA is the density of raptors present on the installation. The abundance of prey items, the distribution and abundance of suitable nesting and perching habitat, and the relative lack of human disturbance have produced one of the highest population densities of hawks and owls found in the state of Colorado. Preliminary surveys conducted during the previous winter showed that hawk densities averaged approximately five to six individuals per square mile. Rough-legged hawks are most abundant during the winter, although ferruginous, red-tailed, and marsh hawks are also common. Golden eagles and prairie falcons are present in smaller numbers. Wintering owls include long-eared, short-eared, barn, and great-horned, with the latter species as the most abundant. During the summer, red-tailed, ferruginous, swainson's and marsh hawks and American kestrels are common. The latter three species are the dominant breeders. Great-horned, long-eared, short-eared, and burrowing owls are also common breeders. In addition, the density of breeding long-eared owls represents one of the highest found in the United States.

6. Mammals - Since the initiation of ecological studies at RMA, 27 species of mammals have been recorded. Although several of these are uncommon, most occur in large numbers.

a. Preliminary small mammal trapping has indicated that very large densities of these animals are present. Among the most abundant are deer mice, prairie and meadow voles, and ord's kangaroo rats. The larger, more conspicuous rodents include the black-tailed prairie dog, thirteen-lined ground squirrel, and fox squirrel. RMA contains some of the largest prairie dog towns remaining in Colorado. Twelve separate towns together cover over 1,000 acres, while one of these towns is over 600 acres in size alone. Another abundant rodent, the plains pocket gopher, is conspicuous due to the mounds of soil it produces at the surface when it excavates its underground tunnels. The densities of this small mammal are very high in areas with sandy soils.

b. Another conspicuous and abundant group of mammals are the rabbits of RMA. Black-tailed jackrabbits are widespread, being especially common in areas with tall grass, forbs, or shrubs. Desert and eastern cottontails are common in and around woodlands, thickets, brush piles, and prairie dog towns.

c. The mule deer is the most important game mammal on RMA. Over the past several years, the population has averaged between 50 and 100 animals. In addition, from one to three white-tailed deer are generally present.

d. The most abundant predatory mammals on the arsenal are the coyote, badger, and long-tailed weasel. Coyotes are frequently observed, especially in winter.

7. Threatened and Endangered Species - Although many species are under review, no plants have yet been officially listed as threatened or endangered by the US Department of the Interior. However, Dr. William A. Weber, professor of natural history and curator of the herbarium at the University of Colorado Museum, has informed us that two rare species may occur on RMA. These are the tulip gentian (*Eustoma russelianum*) and the psoralea (*Psoralea hypogaea*). The tulip gentian was formerly common in wet places on the plains but has become increasingly rare with the disappearance of virgin prairie. If present on RMA, it would probably be found along First Creek. The psoralea is a locally common plant in sandy places on the plains. Neither of these species have yet been observed during field studies at RMA.

a. According to John Davis, Endangered Species Specialist for Region 6 of the US Fish and Wildlife Service, none of the officially listed threatened or endangered fish, amphibians, or reptiles exist in the RMA vicinity.

b. The following endangered, threatened, or rare birds and mammals have been observed on or near the vicinity of RMA:

(1) Peregrine Falcon - Although the pergrine falcon has not been recorded on RMA, it undoubtedly occurs on post periodically, at least during migration. The species is regularly observed during April, May, September, October, and occasionally during winter in the Denver area. Many of these observations have been made at Barr Lake, less than five miles northeast of the arsenal. Most of these observations have probably been of the subspecies *Falco peregrinus anatum*; however, individuals of the subspecies *F. p. tundrius* may have been represented also. Both subspecies are officially classified as endangered. Although *F. p. anatum* has been recorded as nesting as close as Boulder County, the requirement for cliffs as nest sites makes the likelihood of nesting on RMA extremely low.

(2) Prairie Falcon - RMA provides excellent wintering habitat for the prairie falcon (*Falco mexicanus*). Preliminary field surveys conducted during 1975-76 indicate that from two to four individuals inhabited the arsenal during the winter, late fall, and early spring. Like the peregrine, the prairie falcon normally utilizes cliffs for nesting and therefore suitable nesting habitat does not exist on RMA. The species is unofficially listed as threatened by the US Department of the Interior.

(3) Greater Prairie Chicken - The subspecies *Tympanuchus cupido pinnatus* formerly inhabited RMA but was extripated in the region probably prior to the arsenal's establishment due to habitat destruction and market hunting. However, birds were observed as late as 1936 at Barr Lake. Marginal habitat probably exists for this subspecies at present on the arsenal. It is unofficially listed as threatened by the US Department of the Interior.[1]

(4) Spotted Owl - The habitat of the spotted owl (*Strix occidentalis*) normally consists of densely forested areas. Therefore, RMA would not even be considered as marginal habit for this species. However, an adult spotted owl was observed on three consecutive days in early Jun 75 on RMA. This was the first verified sighting of this bird in the state of Colorado since 1963. It is doubtful that the species will ever be observed again on RMA. The spotted owl is listed as threatened by the US Department of the Interior.[2]

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[1] US Department of Interior, Fish & Wildlife Service. 1973. Threatened Wildlife of the United States. Resource Publ. 114.

[2] ibid.

c. In addition to the threatened or endangered birds discussed above, many other birds have been unofficially listed as status-undetermined by the US Department of the Interior. A status-undetermined species or subspecies is one that has been suggested as possibly threatened with extinction, but about which there is not enough information to determine its status. Status-undetermined birds for which suitable nesting, wintering, or resting habitat during migration exists on RMA are the white-faced ibis (Plegadis chibi), ferruginous hawk (Buteo regalis, American osprey (Pandion haliaetus carolinensis), prairie merlin (Falco columbarius richard-sonii), western snowy plover (Charadrius alexandrinus nivosus), mountain plover (Eupoda montana), northern long-billed curlew (Numenium americanus parvus), and the western burrowing owl (Speotyto cunicularia hypugaea). The ferruginous hawk is a fairly common permanent resident and probable breeder on RMA, the burrowing owl is an abundant summer resident and breeder in the prairie dog towns of RMA, the prairie merlin is a rare but regular winter and spring resident, and the white-faced ibis is regularly observed during spring migration. The other birds have not yet been recorded from RMA, although they are regularly observed in the general area.

d. In addition to the species listed as nationally threatened or endangered, the Colorado Division of Wildlife has listed two species which may periodically occur on RMA as endangered within the state. These are the white pelican (Pelecanus erythrorhynchos) and the greater sandhill crane (Grus canadensis tabida). Neither of these have yet been recorded from RMA, however, both are observed regularly in the area. Furthermore, fairly large numbers of white pelicans have summered at Barr Lake in recent years.

e. Finally, in addition to the birds discussed above, 18 species of birds (which have been observed on RMA) have been included by the National Audobon Society on their "Blue List." This list represents those species which, in all or in a significant part of their range, currently exhibit potentially dangerous, apparently noncyclical population declines.

f. Black-Footed Ferret - The black-footed ferret (Mustela nigripes) is the only threatened or endangered mammal which may occur on RMA. This species is officially listed as endangered and is considered very close to extinction. The extensive prairie dog towns on RMA would provide ideal habitat for this mammal, and it is likely that the species formerly inhabited the area occupied by the arsenal. Records show that there have been no confirmed sitings in the RMA vicinity since 1914 and none in the State of Colorado since 1946. Specific efforts were made on three nights in mid Aug 75 to search for the nocturnal mammals with spotlights. None were found. Nevertheless, a remote possibility still exists that a small population of these elusive mammals is present.

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APPENDIX D

ULTRAVIOLET LIGHT WITH OZONE TREATMENT

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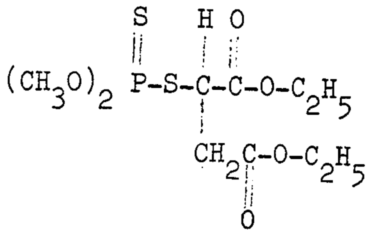
Background

The value of ozone as an oxidant was established at the beginning of this century. In the Organic Chemist's laboratory it has become a standard method of oxidation and is used extensively on both organic and inorganic compounds. For many years, it has been used worldwide as a polishing agent and as a disinfectant for potable water. During the present decade, utilization of ozone in industrial and municipal waste water treatment has expanded rapidly. Since increased attention is being given to refractory organic compounds in waste water effluent, ozonization is becoming a cost effective way to solve difficult treatment problems. Ozone is being used to oxidize stack gas sulfur, nitrogen compounds, chlorinated hydrocarbons, electroplating and photographic wastes (cyanides), slaughter-house waste, phenols, polychlorinated biphenyls (PCB's), and a plethora of other insidious contaminants currently finding their way into water supplies. It has been repeatedly demonstrated that ozone reduces the TOC of waters refractory to other methods of treatment.

The utilization of ultraviolet (UV) light to enhance the ozone oxidation process is an interesting (and rewarding) application of theory. A photochemical reaction is unique in that it deals with the interaction of light with molecules. Because of this interaction, reactions of electronically excited molecules usually occur from completely different energy levels than those encountered in thermal or ground state systems. Absorption of electromagnetic radiation places the excited molecule in a complex situation. The molecule is now faced with a variety of photophysical processes by which it can either return to its original ground state or undergo further photochemical processes resulting in molecular alteration. Introduction of ozone (itself electronically unstable) to the molecular environment at this point causes chemical bonds to break and reform as the ozone and the electronically excited molecules combine to form an ozonide which, in the case of organic compounds, cleaves to yield two simpler compounds. The excitation/oxidation process then repeats itself until compounds incapable of further oxidation are formed (e.g., CO_2, H_2O, Cl_2, P_2O_5, SO_3, etc.).

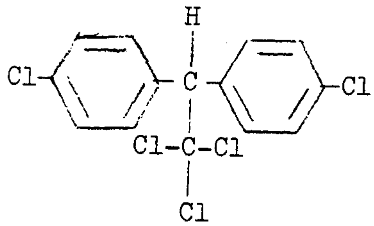
Ozone oxidation of organic compounds.

2  $+ 64\ O_3 \longrightarrow 19H_2O + 20\ CO_2 + 4\ SO_3 + P_2O_5 + 64\ O_2$

(Malathion)

Theoretical O_3 required

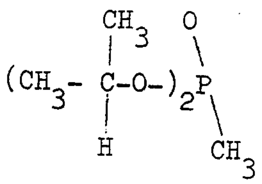
$= 4.65$ mg O_3/mg malathion.

2  $+ 65\ O_3 \longrightarrow 28\ CO_2 + 9\ H_2O + 5\ Cl_2 + 65\ O_2$

(DDT)

Theoretical O_3 required

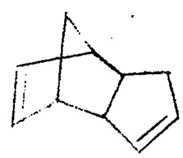
$= 4.4$ mg O_3/mg DDT

2  $+ 45\ O_3 \longrightarrow 14\ CO_2 + 18\ H_2 + P_2O_5 + 45\ O_2$

(DIMP)

Theoretical O_3 required

$= 5.9$ mg O_3/mg DIMP

 $+ 26\ O_3 \longrightarrow 10\ CO_2 + 6H_2O + 26\ O_2$

(DCPD)

Theoretical O_3 required

$= 9.45$ mg O_3/mg DCPD

Most chemical compounds are readily oxidized by ozone. Some conversions cited in the literature include sulfides to sulfoxides, sulfoxides to sulfones, phosphites to phosphates, and primary and secondary amines to nitro compounds and various decomposition products. The degree of oxidation achieved depends on the usual variables of a chemical reaction, e.g., concentration of reactants, length of reaction time, and temperature.